THE AMERICAN NATURALIST

Vol. LXVII *May–June, 1933* No. 710

THE AMERICAN SOCIETY OF NATURALISTS

THE EFFECTS OF HEREDITARY AND ENVIRONMENTAL DIFFERENCES UPON HUMAN PERSONALITY AS REVEALED BY STUDIES OF TWINS[1]

PROFESSOR H. H. NEWMAN
THE UNIVERSITY OF CHICAGO

In this discussion I do not propose to broach the question: Which is more important, heredity or environment? Such a question is meaningless in the raw form. The question I do propose to ask is quite different—With regard to certain physical, mental and temperamental characters in man, what are the relative potencies of hereditary differences and of environmental differences in determining the end result?

If it were possible to control human breeding so as to produce pure lines and to subject part of a pure line to one type of environment and part to another, it would be relatively easy to determine to what extent differences are genetic and to what extent environmental. In the present state of society no such ideal type of experiment is likely to be permitted for a long time. Therefore, we must resort to other methods of investigating the factors of heredity and environment. Fortunately, the study of resemblances and differences in twins offers us a very good method of isolating the inherited aptitudes from the influence of environmental differences in certain

[1] Paper read at the symposium of the American Society of Naturalists on "Heredity and Environment in Man," Atlantic City, December 30, 1932.

human beings. In other words, twins afford an almost complete substitute for a controlled scientific experiment.

Let me explain. Identical twins reared together constitute a control group in which, for each pair, heredity is the same and environment as nearly as possible the same. Fraternal twins reared together constitute one experimental set-up. Fraternal twins have had a common prenatal and a common post-natal environment. They differ from the control only in one factor, namely, heredity, and hence any greater differences found in the experiment than in the control may be attributed to the varying factor, differences in heredity.

Fraternal twins, however, do not give the heredity factor a fair chance to show its potentialities, for fraternal twins are closely related genetically, being brothers or sisters, and are therefore much more similar genetically than would be pairs of persons of the same race chosen at random. I think it would be fair to both heredity and environment to consider fraternal twins as on the average 50 per cent. genetically similar and 50 per cent. genetically different. Even this estimate probably favors the environment factor and disfavors the heredity factor. If then only a 50 per cent. hereditary difference produces certain effects it would be fair to say that a random assortment of unrelated individuals would show twice the effects observed in fraternal twins reared together.

The converse experiment to that just described is one in which the heredity of two individuals is the same, but the environment differs in various ways. Such a set-up is afforded by cases of identical twins separated in infancy and reared apart under different environmental conditions. Greater differences found in separated twins than in those reared together may safely be attributed to differences in the environment.

Realizing the possibilities of substituting twins for controlled experiments, Drs. Freeman, Holzinger and I began about five years ago a program of twin studies.

So far we have studied 50 pairs of identical twins reared together, constituting the control; 50 pairs of same-sexed fraternal twins reared together, constituting the material for testing the potency of hereditary differences; and 10 pairs of identical twins reared apart, constituting the material for testing the potency of environmental differences.

A necessary preliminary to such study of twins is a reliable technique for diagnosing twins as identicals or fraternals. A complete account of our elaborate technique of diagnosis would be impossible in the time permitted. Suffice it to say that we believe we have made few, if any, mistakes. Our statistician, Dr. Holzinger, claims that as many as five mistakes in diagnosing the original 100 pairs of twins would not alter the findings to a significant degree. Let us assume, then, that it is possible to diagnose identical and fraternal twins with sufficient accuracy for our purposes.

All these twins have been extensively studied and measured for physical, mental and temperament-emotional differences, and we have in hand a very large mass of data. Only a bare outline of these data can be given to-day.

A great many physical characters, such as hair color, hair form, eye color, skin texture, distribution of body hair, stature, general body build, shape of hands and feet, ear shape, facial features, shape, size and arrangements of the teeth, etc., are no more different in identical twins reared apart than in those reared together. Such characters, then, are not modified by the existing differences in the environment and may be considered as purely hereditary.

There are, however, some characters in which identical twins reared apart are much more different than identical twins reared together. Such characters may be thought of as partly controlled by differences in the environment. It is only such characters as these that afford an opportunity for testing the relative potencies

of hereditary and environmental differences. Some of these characters are body weight, general physical health and strength, condition or state of preservation of teeth, mental rating in terms of Intelligence Quotients (IQ), temperament-emotional status, as determined by differences in overt behavior and by standard psychological tests. Greater average differences found in identical twins reared apart than in those reared together may be considered as a measure of the effects of differences in environment. These differences may then be compared with differences due to genetic differences as seen in fraternal twins reared together.

In this way we should be able to determine which of the two kinds of differences, hereditary or environmental, produce the larger effects as compared with the control, identical twins reared together. Let us see how this comparison works out with certain sample characters, taking as an example of physical characters body weight and as an example of mental characters the Intelligence Quotient (IQ).

The mean differences in *body weight* for the three groups of twins are as follows:

(1) Identical twins reared together	= 4 lbs.
(2) Identical twins reared apart	= 10 lbs.
(3) Fraternal twins reared together	= 10 lbs.

The two experimental groups, 2 and 3, both show 2½ times as great a mean difference as that of the control. This might be taken to mean that differences in environment have a potency equal to differences in heredity, were it not for the fact that fraternal twins are at most only 50 per cent. different in heredity. Since a 50 per cent. difference gives the same effect as the whole of the environmental differences found in 10 pairs of identical twins reared apart, we may conclude that hereditary differences are about twice as influential as are environmental differences in determining the physical character, body weight.

Much the same situation is found when we study variations in IQ. The mean difference in IQ (Stanford-Binet Test) for identical twins reared together is 5.3 points; that for identical twins reared apart is nearly 9 points; that between fraternal twins reared together a little over 10 points. Roughly speaking, then, differences due to heredity and differences due to environment are both nearly double those in the control, though differences due to heredity are a little greater in their effects than those due to environment. Here again our determination of the effects of differences due to heredity are based on fraternal twins, which are no more than half different in genetic constitution. Once more we shall have to conclude that if a group showing hereditary differences of no more than 50 per cent. gives a certain effect, a group made up of randomly chosen pairs reared together would be expected to show twice as great a mean difference in IQ. From this we may conclude that hereditary differences are about twice as effective in determining differences in IQ as are the differences in environment in the twins reared apart.

Temperament-emotional differences are less easily measured than are body weight and IQ, but there is abundant evidence that heredity and environment have about the same relative effects upon temperamental traits as was the case for body weight and IQ. One indication that this is probably true is seen when we arrange differences in these three characters into three groups, such as great, moderate and slight, and see how many of the ten cases of identical twins reared apart fall into these three classes. For body weight 4 pairs show great, 4 pairs moderate and 2 pairs slight differences. For IQ 4 pairs show great, 4 pairs moderate, 2 pairs slight differences. For temperament-emotional traits 4 pairs show great, 3 pairs moderate and 3 pairs slight differences. The distribution is nearly the same for all three traits, an indication that they are about equally effected by differences in heredity and those in environment.

So far as our materials go, we may say, then, that the actual differences in heredity have about twice as great an effect as do the actual differences in the environment in producing the differences observed in such characters as body weight, IQ and temperament. This does not mean that heredity is twice as important as environment.

Now the rest of my time shall be devoted to a brief description of the ten cases of identical twins reared apart. This experimental group is at once the most critical and the most difficult to secure. Twins reared together are numerous, but identical twins reared apart constitute one of nature's rarest experiments. Through constant effort and at very considerable expenditure of money, tact, detective ability, and not without much sorrow and disappointment, we have in five years succeeded in getting the data on ten pairs. In every case the twins were separated in real infancy and kept apart for from 13 to 55 years. The environments of the various separated pairs differed markedly in nearly all the cases. It is difficult to imagine environmental differences much greater than those found, unless one were to separate twins in such a way that one was reared in one country and the other in a very different country. It is, however, necessary to have them reared in the same cultural complex; otherwise they could not take the same psychological tests. On the whole we feel that the differences of environment found in these cases represent the normal range of environmental differences likely to be found among people of the same country and speaking the same language. It is doubtful whether a larger number of cases would very greatly modify the size of the mean differences already found, for the mean of the first five is almost exactly the same as that of the second five. If it is true that our ten cases are truly representative, we do not badly need any more cases. I am sure, however, that we shall not stop with ten cases and I hope others will help in contributing cases of their own.

Every case studied is perhaps more interesting and significant as a case study than as an item in a statistical summary. I am therefore going to describe briefly for you the separate cases, showing photographs of each pair. It will be noted that while a pair may differ greatly in one respect there may be only moderate or slight differences in other respects. Also it will be seen that wherever educational differences are very great there is a correspondingly great difference in IQ, wherever the differences in social environment are very great there are great differences in temperament and sometimes in IQ, and that wherever the differences in physical environments are great, there are great differences in physical condition. Slight differences in any of the three features of the environment seem to have no measurable effect.

Case I. Twins "A" and "O" were born in London, England, "A" living there until shortly before we examined them, while "O" was brought to Canada at eighteen months and reared in a medium-sized Ontario town. Quantitatively there was not much difference in their formal education, but there was a great difference qualitatively. "A" studied chiefly domestic subjects, while "O" had a well-rounded high-school course, followed by a business course. The war period in London seriously interfered with "A's" education, while "O" was little disturbed. The physical environment of "A," especially as regards food, rest and sleep during the war period, was in striking contrast with that of "O," living in the quiet, prosperous Ontario town.

At the time of the examination there was a great difference in their physical condition, "O" being much superior, their weights, "A" 92½ pounds and "O" 102 pounds, being diagnostic of their relative condition. In all the intelligence tests given "O" was definitely superior, the difference in IQ in the Stanford-Binet test being 12 points, nearly 2½ times the mean in the control group. Temperamentally, they were remarkably similar, the differences being only slight.

Case II. Twins "E" and "G" were born in New York City, were separated at eighteen months and reared unknown to each other in two Michigan cities. After twenty years of separation they found each other in a purely fortuitous manner, and had been living together for about two years when we studied them. There was no great difference in their physical or social environments, but a very great difference in formal education. "E" went through grade school, high school and two years of normal school, while "G" stopped school after the fifth grade in order to help with housework. At the present there is only a very slight difference physically: in fact they

are as similar as any of the pairs of identical twins reared together. There were 12 points difference in Stanford-Binet IQ in favor of "E," the more highly educated twin, and even greater differences in other intelligence tests. Temperamentally they are most strikingly similar. The fact that one is now a doctor's assistant and the other a dentist's assistant, and both eminently satisfied with their jobs, indicates that their personalities are nearly identical.

Case III. Twins "C" and "O" were born in an Illinois village and were early put in an orphans' home, from which they were soon adopted by two families unknown to each other. The twins were entirely separate for twenty years and met for the first time when they were twenty-one years old. They had met only once before when they came to Chicago to be studied. The chief environmental difference was one of city life *versus* rural life. "C" had always lived in rather large cities in Michigan, while "O" had been a village boy in various parts of Illinois. Though living in a rural community he had not engaged actively in farming, but had done mostly clerical work. They both had a high-school education and very little more.

When examined, there was a moderate difference physically, "C" being in better physical condition, better groomed, and weighing 124 pounds as compared with 113¾ pounds for "O." There was no significant difference in mental rating between them, one ranking a little higher in one test, the other in another test. The scores on the Stanford-Binet test were: "C" 99 points and "O" 101 points; while on the Otis test "C" had a score of 110 and "O" 100. On the whole "C" made somewhat higher scores. Temperamentally there was a great difference. It appears that they were no more alike in their emotional reactions than would be two persons chosen at random.

Case IV. Twins Mary and Mabel were born in Ohio about thirty years ago, were separated at five months and reared by relatives. Mabel has lived all her life on a prosperous farm, living the life of an active farm woman. Mary has lived largely a sedentary life in a small town, clerking in a store during the day and teaching music at night. Mabel stopped school after the grade school, while Mary had a full high-school course in an excellent city school near her home. Mabel has always been very healthy, while Mary has been troubled a great deal with a series of severe colds every winter.

At the present time there is a vast difference between the twins in all three respects. Physically, Mabel is robust, muscular and in perfect health, while Mary is much under weight, soft muscled and in poor general condition. Mabel weighs 138½ pounds, Mary only 110¾ pounds, a difference of nearly 28 pounds, about 25 per cent. of the weight of Mary. Intellectually the difference is equally striking, but in favor of Mary, whose Stanford-Binet IQ was 106, as compared with 88 for Mabel. The difference of 18 points is nearly 3½ times as great as the mean of the control, and the largest found in any identical twins studied. The differences were even greater in some of the other tests. Temperamentally these twins may be adjudged at least moderately different, being almost as different in most reactions as was true for the twins of Case III. Yet in a few respects there is an underlying resemblance that stands out sharply.

Case V. Twins "B" and "D" were born in Iowa of extremely young parents who were unable to keep them. They were put in a children's home at an early age and were separated at 14 months, never to meet again till they were sixteen. After a dramatic discovery of each other they lived together for about a year, when "D" married and moved away. There was no marked difference in the physical environment of the twins up to this time. Also their formal education was nearly equal, "B" finishing eleventh grade and "D" tenth grade. The chief environmental difference came after "D's" marriage. She married a poor man, who failed to make a living in Iowa and moved to the far West where he staked a claim and lived the hard, meager life of a pioneer. During this period "D" had four children in rapid succession and two more after moving back East. During the pioneer days food was poor and ill suited for a child-bearing woman. "B" some years later married a well-to-do merchant and has lived a relatively easy life, with domestic help and abundant social opportunities. She has had four children rather well spaced in time.

When examined at the age of 38, these twins showed great physical differences. "B" seemed unusually well preserved, looking hardly over thirty. Her teeth were absolutely perfect and her weight was 110½ pounds. "D," however, looked fully her age. Her teeth were in extremely bad condition, several having been extracted, others badly decayed, and the incisors discolored and badly worn. Her weight was 101 pounds.

Intellectually there is only a slight difference between them, "B's" Stanford-Binet IQ being 93 and "D's" 89. They class as moderately different temperamentally, though their resemblances are more impressive than their differences.

Case VI. Twins Ada and Ida were born fifty-eight years ago in a small town in Ontario and were adopted by two families of relatives when they were three years old. The early life of both twins was equally wretched. Apparently they were unwelcome in their foster homes and were badly abused. They had practically no formal education, attending country school irregularly for only about three years. In school they did not even learn to read. The moral influences in their homes were so bad that they themselves sometimes wonder how they ever grew up to be good women. They were entirely separated for thirteen years. Ada married at seventeen and Ida at thirty-three. Ada has reared five children, Ida four. Ada left her husband after four years, Ida still has hers. Ada has lived partly in the country, but of late mostly in large cities; Ida has always lived in the country.

When examined at the age of 58 these twins were very different physically, owing largely to the fact that Ida has an advanced goiter and was weak and inactive. Ada was strong and active and had no goiter. Ada weighed 208 pounds, Ida 227, a difference of 19 pounds. Intellectually both women made a surprisingly good showing considering the lack of schooling, Ada being moderately superior on all tests, her IQ being 101 to Ida's 93. Temperamentally they were remarkably similar. Both women are now militantly moral, probably as a reaction against childhood influences.

Both are highly respectable and highly respected women. They illustrate the ability of good heredity to surmount bad environment.

Case VII. Twins Richard and Raymond were born in Indiana and separated at one month of age, Raymond being adopted by a prominent physician in a rather large city and Richard by foster parents in less favorable circumstances. Raymond stayed at home and was more sheltered, while Richard was taken about far more, was more thrown on his own resources, and also saw more of the seamy side of life. They had exactly the same amount of schooling and were at 13½ years of age in the same grade, the eighth grade, both among the brightest students in the class.

When examined at the age of 13½ years, there was no difference of any consequence physically. The differences in IQ for all tests were slight, the scores for the Stanford-Binet test being 106 for Richard and 105 for Raymond. Temperamentally, they were moderately different. Richard seemed more positive in all his characteristics and gave a much more normal reaction to such tests as the Kent-Rosanoff Association test. Hence the only significant different between these twins is a moderate difference in temperament.

Case VIII. Twins "M" and "R" were born in Indiana and were separated at three months, "M" being adopted by a maternal uncle, and "R" by a brother of "M's" foster mother. "M" was reared in a town of 5,000 population, where she knew nearly everybody in town and had many friends and playmates. Her foster father was a leading citizen, well educated and had a cultured home, involving good books, good music, etc. "R's" home was relatively narrow and unstimulating. Neither of her parents had much education and, although living in a large city, she had but few friends and made but few social contacts. In fact, she was kept closely at home. The environmental contrast is that of a stimulating and cultured home environment *versus* a depressing and uncultured home environment. There was very little difference in the schooling of the two girls, "M" attending school at home and being now in grade 10A, while "R" has attended a good city school and is in 10B. The physical environment has been about the same for the twins.

When examined at about 15 years of age the girls were remarkably similar physically. There was a great difference in intelligence, "M" being distinctly superior in all tests, "M's" score on the Stanford-Binet test being 92 and "R's" 77, a difference of 15 points, greater than that found in Cases I and II. This great difference must be the result of differences in informal education. Temperamentally the differences are great both in overt behavior and in reactions to tests. "R" is extremely timid and retiring. She lisps markedly and seems unhappy. "M" seems quite normal in behavior. The tests all show about the same contrasts.

Case IX. Twins Harold and Holden were born in Wisconsin and separated in early infancy, but have lived only three miles apart. Harold has lived in a village and has not done much manual labor, while Holden has lived on a dairy farm and has worked ever since he was old enough to be useful. They attended different grade schools but were graduated from the same high school, Holden one year ahead of Harold. Harold has had much

more opportunity to engage in group activities, while Holden has been denied this. The differences in environment have not been at all marked, less so than any other of our cases.

When examined at 17 years of age these boys differed slightly in all respects but were almost as similar as the average pair of identical twins reared together. The Stanford-Binet test gave Harold a score of 102 and Holden a score of 96. Harold was somewhat superior in all other mental tests. Holden was somewhat superior physically in most respects, but both seemed to be in perfect physical condition. Temperamentally, the differences were rather marked in some respects, Harold appearing rather more normal. On the whole it is necessary to diagnose all three types of differences as "slight," though the mental differences are almost "moderate."

Case X. Twins "B" and "J" (described by H. J. Muller). This case was the first one studied and should have been described first, but my cases have already been numbered from I to IX. These twins were born in a South Dakota mining camp and were separated at two weeks. "B" was brought up by foster parents engaged in mining and hauling. She had four years of formal schooling and nine months in a business school. Since she was fifteen she has had an active business career, being in France during and after the war. Her life has been more varied and rougher than that of "J." "J" was reared by well-to-do parents who owned a ranch and a tourist hotel. She went through grade school, high school and attended some summer sessions at the university. She is a school teacher by profession, though she married at 21 years of age and has one son.

When examined at 27 years of age, these twins were nearly identical physically. They were also nearly identical mentally, "B" having an IQ of 156 and "J" of 153, both very high, "B" the less educated twin having the higher score. Temperamentally they appear to be no more alike than two women chosen at random.

It is fully realized that these brief summary descriptions of the ten cases are entirely inadequate, but they serve to bring out a few of the salient facts. Case studies of Muller's case and of our first six cases have already been published in the *Journal of Heredity* and Cases VII, VIII and IX are now in press in that journal. At a later time Drs. Freeman, Holzinger and I expect to publish, probably in book form, as complete an analysis of these ten cases as we are able to make. Any conclusions stated in this and other papers already published must be considered as tentative and subject to alteration should further analysis warrant it.

In the descriptions of the ten cases just given more emphasis has been placed upon differences than upon re-

semblances. This has seemed necessary in order that such differences as do exist may be brought out at all. We have, for example, considered differences in IQ of 12 points or over (Cases I, II, IV and VIII) as great differences, though I am well aware that psychologists claim that differences of this magnitude may occur when a given person takes the same test twice. The largest difference found was one of 18 points, which psychologists do not consider as more than a minor one. Differences of these dimensions assume greater significance, however, when it is stated that the majority of identical twins reared together show differences of from 0 to 3 points in IQ, and that the mean difference of 5.3 points is produced by half a dozen exceptional pairs that show differences of 10 points or over. There is no reason, however, for insisting that the observed differences in IQ or in other respects are really great. Our only concern has been to give a fair emphasis to the actual differences observed. Any over-emphasis upon the effectiveness of environmental differences is certainly corrected when the mean differences with regard to the various traits is determined.

As previously shown, these mean differences for the separated identical twins turn out to be approximately the same in extent for body weight, IQ, and perhaps also for temperament, as the mean differences found in fraternal twins reared together. What interpretation may be placed on these figures? On the assumption *a,* that one fraternal twin in a pair differs from the other on the average about as much as would two persons chosen at random, and *b,* that the environmental differences encountered by two identical twins reared apart are on the average about as great as those encountered by two persons chosen at random, hereditary and environmental differences might be said to have about equal potencies. These two assumptions, however, demand scrutiny. The first assumption is obviously unjustified, for it can be shown in a great variety of ways that the hereditary dif-

ferences between fraternal twins are no greater than between sibs and that sibs differ on the average about half as much as do persons of the same race chosen at random. If this be granted, it would follow that if hereditary differences were given full play the effect of these differences would be about twice as great as those found in fraternal twins reared together. Since the mean differences found in fraternal twins reared together are at least equal to those of identical twins reared apart it would be fair to conclude that randomly paired individuals reared together would show a mean difference twice as great as that found in identical twins reared apart. The second assumption may also be unjustified, for we have no assurance that the actual differences of environment between these separated twins average as great as those likely to be found between pairs of individuals chosen at random. It seems to me, however, that the actual differences in environment in these ten cases represent about the full range of such differences likely to be encountered by persons of the same race living in the same country. Our conclusion stands or falls on the basis of the justifiability of this assumption, and has to do with such modifiable characters as body weight, general health and physical condition, IQ, and temperament-emotional traits. There can be no doubt, of course, that more extreme environmental differences than those encountered by our twins reared apart would result in proportionately greater differences. All that our studies of twins tend to show is that, in a given country, the actually existing hereditary differences are likely to be about twice as effective in determining the exact status of certain modifiable personal characteristics as are the environmental differences likely to be encountered.

NEEDED EVIDENCE[1]

DR. BARBARA S. BURKS

INSTITUTE OF CHILD WELFARE, UNIVERSITY OF CALIFORNIA

THE problem of determination of mental ability through the influences of heredity and environment has been recognized as a fertile research field since Galton in 1869 published his much quoted study of "Hereditary Genius." Though nature and nurture each had strong advocates dating from the time of Plato and before, it was not until Galton's pioneer work that an effort was made to view the problem scientifically and to advance beyond speculation, uncontrolled observation and anecdote. Now, thanks to the mass of careful work which has been accumulating since Galton's time, and particularly during the last ten years, it is possible to accept certain conclusions with reasonable assurance that they represent what is true rather than what could conceivably be true. However, there are still certain controversial issues—hence the symposium of which this paper is a part.

The present paper is limited chiefly to a discussion of evidence regarding intelligence, the mental trait concerning which the most data are available, and about which there should be correspondingly the least controversy. Parenthetically, it may be said that there is cogent reason, both *a priori* and by the results of experiment, to believe that personality traits are more influenced by nurture than are the more intellectual variety of mental traits. We must distinguish between what a person *can* do—the difficulty of mental performance which he is able to attain (intelligence) and what he *will* do—which of the many courses of behavior within his physical and mental capacity he will characteristically take (personality).

[1] Paper read at the symposium of the American Society of Naturalists on "Heredity and Environment in Man," Atlantic City, December 30, 1932.

Historical Advance of Problem and Methods of Approach

The history of the subject has more than ordinary interest because all the historic approaches are still currently used, sometimes, to be sure, to the discredit of the field.

As in other developments in science, a typical sequence can be observed, beginning with the gross drift out of which an originator like Galton could discover a pattern, and ending with crucial, quantitative work. We may use such a device as is much in favor by geneticists for illustrating the sequence of results in terms of the techniques employed to obtain them. Listed vertically are some

Historical Development of Nature-Nurture Problem
Method

Status of knowledge	Study of ability of family lines	Biometric study of family resemblance	Biometric study of twin resemblance	Statistical study of ability in social and racial groups	Experimental technique	Special studies of data on family resemblance
A. Definition of the problem	X	X	....	X	....	....
B. Unquantitative determinations:						
Influence of heredity	....	....	X	X	Orphans Animals	....
Influence of environment	....	....	....	X	....	....
C. Quantitative determinations:						
Estimates of ability	X	X	....	....	....	....
Influence of heredity	....	....	Co-twin control; twins reared apart	....	Foster children	X
Influence of environment	....	....	Co-twin control; twins reared apart	....	Foster children	X
D. Mechanism of heredity						
Mode of transmission	....	....	....	....	Animals	X
Linkage	....	....	....	....	....	X

rubrics indicating the progressive status of our knowledge, while horizontally are listed the modes of attack. The crosses and notations in the checkerboard show the relationship between the types of data collected and the types of knowledge they contribute. We may take up for discussion one by one the various types of available data (horizontal list) and examine the residues they leave.

Study of High and Low Ability in Family Lines

The early work of Galton set the pattern for this type of study; and until about 1900 it was virtually the only kind carried out. Counts were made of the eminently able individuals of certain family stocks, and of the defective individuals of others. Casual observations of the facts of family resemblance such as any one might make were thus replaced by statistical formulations of the tendency for one or the other extreme of ability to cluster in family lines. The eminent men studied by Galton, the gifted Jonathan Edwards clan (Winship, 1900), and the notorious aments and paupers of the Jukes (Winship, 1900) and Kalikaks (Goddard, 1912) of America furnish such dramatic material that their histories have been and still are summarized in practically every text-book touching upon mental heredity in man. Such studies are designated on our checkerboard as defining the existence of the nature-nurture problem. They permit in a limited way an estimate of the ability of the relatives of an individual of great or meager ability. Beyond this, however, they do not go, for there is nothing within such data enabling us to untangle the effects of nature and nurture. Moreover, their value for prediction is extremely limited. It is of little general usefulness to be able to say that a man of genius is 134 times as likely as a random man in the street to have an eminent relative.

Biometric Study of Family Resemblance

Pearson, with his series of correlation studies initiated in about 1900, set the pace for a large group of subsequent workers. Pearson's studies were based upon trait

ratings, whereas later studies have been facilitated by superior measures from mental tests.[1] The correlation between mental ability of relatives of the first degree (parents and offspring, brothers and sisters) has been established as about .50, an amount which checks well with the correlations found for hereditary physical traits, and which checks also with the theoretical expectation on a Mendelian hypothesis of cumulative, non-dominant genes. These studies are of value in making possible predictions of the ability of individuals whose parents or other relatives are of known mental level, but do not enable us any more than do the "incidence" studies to separate nature and nurture and attribute the observed facts to one or the other. An environmental hypothesis rather than one of Mendelian inheritance might conceivably account for the correlations.

Biometric Study of Twin Resemblance

A good many investigations of twins have accumulated since Galton himself saw the need for something more informing than his own "incidence" studies. He collected data (1883) showing that twins of the identical or uniovular type tend to remain very similar throughout life, while twins of the fraternal or biovular type tend to retain the dissimilarities with which they start in childhood. The later studies (particularly by Merriman, 1924; Lauterbach, 1925; Wingfield, 1928; Holzinger, 1929; Hirsch, 1930) express the resemblance of identical and fraternal twins in terms of correlation coefficients. They show that pairs of identicals resemble one another almost as much as an individual resembles himself when tested twice with a short time intervening (about .90), while pairs of fraternal twins resemble one another little if any more than do ordinary siblings (about .50).

This type of study has been designated on our checkerboard as demonstrating the influence of heredity, since

[1] Some of the most extensive family resemblance studies have been carried on by Rensch, 1921; Hart, 1924; Hildreth, 1925; Jones, 1928; Burks, 1928; Thorndike, 1928; Willoughby, 1930.

the children with identical heredity are much more alike on the average than are those whose hereditary potentialities are determined by different gametes. It is hardly possible, however, to draw any quantitative conclusions from such data, even though the correlations give the illusion of precision. We do not know to what degree environment may have contributed to the resemblances of both types of twins. The several formulas which have been proposed for appraising on the basis of correlations the relative contributions of nature and nurture are ambiguous, since they assume the environments of the two types of twins to be equally equal, an assumption subject to unknown error. (See preliminary study of differential environmental differences by Wilson, 1932.) Moreover, even if these formulas could accurately separate nature and nurture contributions to twin pair differences, this would be without general interest, since inferences can not be drawn therefrom regarding the causes of variability among individuals at large.

From studies of co-twin control (Gesell and Thompson, 1929; Strayer, 1930), and of twins reared apart (Muller, 1925; Newman, 1929–1932), really quantitative data may be ultimately expected. The number of cases of either kind is not yet sufficient to warrant definite conclusions, though it is significant that the mental test scores reported for ten sets of identical twins reared apart show a somewhat greater average discrepancy than is typically found for twins reared together. One difficulty in studies of twins reared apart is that members of a pair are often placed selectively, occasionally even with close relatives. The obtained results are therefore only minimum estimates of the mental disparities which truly random environmental differences might be expected to yield.

Statistical Study of Ability in Social and Racial Groups

Studies of mental differences among people of different social, educational or racial groups have sometimes been

cited as evidence for the influence of heredity. The position might better be taken that the existence of such differences are simply additional indication of the nature-nurture problem itself, to be examined with the same caution and subject to the same pitfalls as are other indications of the problem. The writer knows of no really crucial studies upon race differences in intelligence. There are several studies, however, which suggest a measurable effect upon mental development of extreme educational deprivation, and several which suggest that ordinary differences in education or cultural opportunities have little effect upon differences in mentality. Children who lived all their lives upon canal boats in England (Gordon, 1923), showed a pronounced inverse correlation between age and mental standing. On the other hand, little relationship has been found between total school attendance and IQ among school children of a given age in urban communities (Heilman, 1928; Denworth, 1928).

Although a number of investigations show rural children to average distinctly lower in IQ than do city children, two studies made in England indicate that this difference is probably largely native, and due to selective migration of the higher levels of ability to the cities. The English investigators found as others had before them a lower average mental level among children in ordinary rural settlements. However, children in very remote rural areas, where little "drainage" to the cities had taken place, averaged as high in ability as city children. (Bickersteth, 1919; Duff and Thomson, 1923.)

Additional light upon the origin of mental differences associated with social status may be found in several of the studies summarized in the next section.

Experimental Technique

It is probably a safe generalization that a field of investigation becomes scientific in proportion as experimentation becomes possible and is utilized. In the field with

which we are concerned the studies which resolve rather than stimulate controversy are nearly all of an experimental kind, though often the experiment is set and conducted by certain agencies of our social structure whose aims are remote from research. As psychologists, biologists or sociologists, we are sometimes able to step in and measure the results of such experiments. This has been done particularly with children reared in orphanages and with foster children. Studies of twins reared apart might also be mentioned here as a special case of the foster child approach, though it seemed more appropriate to discuss the significance of such studies in the general section on twins, p. 209, *ff*.) Gesell's co-twin control studies are among the few involving actual experimentation by the investigator, but were classified also in the general section on twins.

In the studies of orphanage children, living of course in a relatively uniform environment, it is extremely interesting that differences persist in the average IQ's of children whose parents were of varying occupational or educational levels. (Jones and Carr-Saunders, 1927; Lawrence, 1932). Although children of differing origin do show somewhat smaller differences than usually appear between corresponding groups of children reared in their own homes, it is not known whether this fact must be attributed to a leveling influence of orphanage life, or to selection as to the type of dependent child who receives institutional placement.

Several studies which show the correlation between the IQ's of siblings reared in orphanages to be almost, if not quite, as high as between siblings reared in their own homes give rather cogent evidence for the influence of heredity, although the possibility is not ruled out that home and family influence in early childhood years may have made at least some contribution to sibling resemblance. (Gordon, 1918–20; Hildreth, 1925; Davis, 1928.)

Investigations employing animals have a great advantage over those employing human subjects, in that all

may be reared under the same carefully controlled conditions. Except for such small effects as may be assigned to inter-uterine environment or to nutrition in the early weeks of life, the family resemblances which several investigators have found in the maze-running ability of albino rats must be attributed to nature (Tolman, 1924; Burlingame and Stone, 1928; Tryon, 1929). In the Tryon studies a very significant hereditary effect has been demonstrated through eight generations of selective breeding for "brightness" and "dullness" in maze-running. Two strains have been developed with practically no overlapping of ability. The strains offer extremely valuable material for testing various hypotheses as to the mode of transmission of the particular mental trait measured, and further work is planned by Tryon toward this end.

It is through studies of foster children adopted in infancy that we should be best able to obtain a quantitative determination of the effects of nurture, and by inference, the complementary effect of nature. There are three large-scale studies of foster children (Theis, 1925; Burks, 1928; Freeman, Holzinger and Mitchell, 1928), though only the second and third employ mental tests. These two, conducted at Stanford and Chicago, respectively, agree in certain important respects, and disagree in others. Let us consider the main findings in the light of methods used.

Groups studied: The Chicago group contained various subgroups aggregating about 400 children in all. The group was heterogeneous with respect to race and age of placement, and ranged (with a few exceptions) from three to eighteen years at time of test. In the Stanford study subjects consisted of about 200 foster children and 100 control children reared with their own parents. The subjects were all of white "American" or North-European stock, so chosen in order to guard as far as possible against selective placement. The children ranged from five to fourteen years at time of test. All were placed when under a year of age.

Comparative Methods and Results: IQ's of children in both studies were measured on the Stanford-Binet. Mental ages of adults were measured on the Stanford-Binet in the Stanford study, and on the Otis in the Chicago study. A composite environmental home rating was obtained by somewhat different methods in the two studies, though each was concerned both with the material level and the cultural standards of the home.

Comparative correlations:	Stanford	Chicago
IQ of foster child vs. MA of foster father	.07	.37
IQ of foster child vs. MA of foster mother	.19	.28
IQ of foster child vs. environmental rating	.39	.48
IQ of child vs. MA of own father	.45	.....
IQ of child vs. MA of own mother	.46	.....

That the higher correlations found in the Chicago study may be due at least partly to selective placement rather than to environmental influence is suggested by the results from the Chicago "pre-test" group of children who were old enough to test before entering foster homes. Their IQ's before placement correlated .34 with the environmental rating. After an average foster home residence of four years, IQ's and environment correlated .54. This increase, while showing a real if relatively small effect of environment, brings the correlation to only a little above the value found for the children who were too young to test at time of placement. It therefore seems a fair inference that some degree of selective placement influenced the results for the entire Chicago group. Miss Leahy (1932) in her study of Minnesota adoptions found appreciable evidence of selective placement.

Other significant findings in the Chicago study were: A correlation of .34 between the IQ's of 125 pairs of siblings reared apart. This correlation becomes .44 if only white children between the ages of five and fourteen are used, and is then approximately equal to that found for siblings reared under normal circumstances.

A correlation of .31 between the IQ's of 112 pairs of foster siblings, *i.e.*, unrelated children reared in the same home. It is probable that this correlation is partly due to selective placement.

An average increase of about 7 points in the IQ's of the pre-test group after four years of residence in good foster homes.

Conclusions: The authors of the Chicago study concluded that environment was an important factor in their results. The one really quantitative appraisal of the effect of environment was made in the pre-test group, which showed an average increase in IQ of 7 points. At Stanford the conclusion was drawn that measurable home environment contributes about 17 per cent. to the variability of children in such communities as were studied; that superior foster home environment had raised the IQ's of the subject about 7 points, and that extremely superior or inferior environment might alter the IQ by as much as 20 points. It was further concluded that since the correlations established between parents and offspring in the control group show good agreement with theoretical expectation on a genetic interpretation, heredity probably accounts for most of the variability in the children's ability.

The discrepancies between the Stanford and Chicago studies are not as serious as they might appear at first glance, but it would be highly desirable to get them explained and ironed out. We may hope that Miss Leahy's extended research on foster children, now in progress in Minnesota, may resolve the difficulties.

Special Study of Data on Family Resemblance

Only a few studies, other than the Stanford investigation just summarized, have attempted to reach a numerical estimate of the proportional contributions of nature and nurture to mental differences, or to explain the mechanics of the transmission of mental traits.

Willoughby (1927) used Fisher's method (1918) of estimating the relative contributions of nature and nur-

ture to physical traits on the basis of the discrepancies between parental and fraternal correlations. The estimate yielded relative contributions of about 50–50, but it is doubtful whether Fisher's method is at all applicable in Willoughby's study of mental traits, since environment is assumed by Fisher to operate by chance to *lower* correlations, instead of systematically to raise them.

Ruth Sherman Tolman and the writer (1932) compared the mental resemblance of sibling pairs who were very similar in physical appearance with that of sibling pairs who were less similar in physical appearance. The problem was approached under the supposition that chromosome linkage might be demonstrated between physical and mental composites due to many genes. Since siblings very similar in one composite would theoretically have an unusually high number of chromosomes in common, they should tend toward high resemblance in any other traits whose genes were located in some of the same chromosomes. The results of the Burks-Tolman investigation were negative. It is possible that the criterion for selection of the sibling groups was not sufficiently rigorous. Further work along this track might yield results of considerable interest.

RECAPITULATION

Out of the evidence which has been accumulating since Galton raised the nature-nurture problem from the level of mere speculation, what do we now know or feel fairly sure of? It seems clear:

That mental abilities in man cluster in family lines, and in racial and social groups.

That one can predict the intelligence of relatives of individuals of known intelligence with known accuracy or inaccuracy; and that even if heredity solely accounts for mental variability, children of the same family will differ, because they have differing heredity.

That complete deprivation of schooling probably has a depressing effect on the IQ, but that ordinary differ-

ences in education probably exert little influence upon the IQ.

That intellectual differences found between urban and rural children are probably due in large part to selective drainage of the higher levels of ability to the cities.

That measurable home environment probably contributes about 17 per cent. to children's mental variability, and that the major share of the remaining variability is probably due to heredity. It is likely that home environment at its best or worst can enhance or depress the IQ by about 20 IQ points.

That a cumulative Mendelian factor mechanism probably accounts for the transmission of intelligence, since all known heredity traits, including the mental traits, fit the Mendelian hypothesis, and environment demonstrably can not account for the correlations.

Needed Evidence

The foregoing recapitulation, which most students of the field would agree could not be greatly extended through any facts at present available, contains the vital and central conclusion that mental ability is chiefly inherited. There are nevertheless ramifications of the problem which are in need of greater clarification. Because the number of contributors to this symposium is so small, the present contributor has taken soundings from other interested people. We may recall that Cattell has expressed the conviction that every scientist's best work is based on the original ideas he had before the age of twenty-five. Accordingly, several now or recently from the graduate student group as well as those known for their work in the field have been asked for suggestions.

A number of those consulted seem to have the view that like a chemist who controls the environment of his compound with respect to pressure, temperature, surrounding atmosphere and surface of container, we too must control our experiments, and not look to much help

from the sticky fly paper technique of catching up data which simply happen to be there.

The suggestions group themselves about environmental influences—including home, schooling, community and general life experiences—and heredity—including race and genetic mechanism. Projects contemplated by the writer are included with those proposed by others.

Home Environment

Alice M. Leahy, Institute of Child Welfare, University of Minnesota: Would like to see the discrepancies resolved between Stanford and Chicago studies of foster children. Is working now upon a carefully planned investigation which promises to do so.

Harold E. Jones, Institute of Child Welfare, University of California: Proposes the establishment, in cottage communities associated with two comparable factories under single management, experimental and control groups for determining the influences of environmental variables such as feeding, discipline, nursery school attendance, cultural advantages in the home, etc.

Frank Lorimer, Washington, D. C.: Wishes to test the possible differential effect of home environment upon different levels of ability; also to test the facilitation of mental growth through intensive instruction in language in earliest childhood.

Barbara Burks, Institute of Child Welfare, University of California: Plans if the opportunity offers to establish an institution in which infants relinquished by their mothers may be reared for a term of years subject to various methods of conditioning.

Lewis M. Terman, Stanford University: Still subscribes to what he has termed *the* experiment—the selection of a large group of sibling pairs from an unfavored environment, one member of each pair to remain in the original milieu, and the other to be reared in a superior environment.

Schooling Effects

Bronson Price, graduate student, Stanford University: Suggests the experiment of introducing schools into poor mountain white communities having no educational facilities, and measuring the mental traits of children before and after attendance.

Community Effects

Sidney Adams, graduate student, University of California: Would like to test the hypothesis that the intellectual level of a community affects the intelligence of all its members, by evaluating the cumulative effect of selective emigration upon those who remain.

Combined Life Experiences

Harold Carter, Institute of Child Welfare, University of California: Plans to devote a great deal of time to the study of adult identical twins separated for varying periods of years.

Barbara Burks: Wishes to study overlapping effects of various environmental influences,—to ascertain, for example, whether the separate contributions of nursery school, home, stimulation through reading to a child or teaching him number work, etc., are additive, partly additive, or mainly overlapping.

Race

An inter-racial orphanage was proposed several years ago by the Social Science Research Council.

Genetics of Mental Heredity

Herbert S. Conrad, Institute of Child Welfare, University of California: Will be satisfied with nothing less than a three-generation study of the transmission of mental traits.

Barbara Burks: By establishing the regression of offspring on parents at different ability levels, will approach the problem of dominance and recessiveness in mental traits. Would like to continue approach to genetic linkage as described on p. 216 *ff*.

Robert Tryon, University of California: Through experiments in breeding rats on the basis of maze-running ability, hopes to illuminate the general problem of the transmission of mental traits. Wishes to obtain homozygous strains of rats, and then to experiment with specific environmental influences and with cross matings.

LITERATURE CITED

M. E. Bickersteth
1919. "The Application of Mental Tests to Children of Various Ages," *Brit. Jour. Psych.*, 9, 23–73.

B. S. Burks
1928. "The Relative Influence of Nature and Nurture upon Mental Development," *27th Yearbook N. S. S. E.*, I, 219–316.

B. S. Burks and R. S. Tolman
1932. "Is Mental Resemblance Related to Physical Resemblance in Sibling Pairs?" *Jour. Genet. Psych.*, 40, 3–15.

M. Burlingame and C. P. Stone
1928. "Family Resemblance in Maze-Learning in White Rats," *27th Yearbook N. S. S. E.*, I, 89–99.

R. A. Davis
1928. "The Influence of Heredity on the Mentality of Orphan Children," *Brit. Jour. Psych.*, 19, 44–59.

K. M. Denworth
1928. "The Effect of Length of School Attendance upon Mental and Educational Status," *27th Yearbook N. S. S. E.*, II, 67–91.

J. F. Duff and G. H. Thomson
1923. "Social and Geographical Distribution of Intelligence in Northumberland," *Brit. Jour. Psych.*, 14, 192–198.

R. A. Fisher
1918. "Correlation between Relatives on the Supposition of Mendelian Inheritance," *Trans. Roy. Soc. Edinburgh*, 52, 399–433.

F. N. Freeman, K. J. Holzinger and B. C. Mitchell
1928. "The Influence of Environment on the Intelligence, School Achievement and Conduct of Foster Children," *27th Yearbook N. S. S. E.*, I, 103–217.

F. Galton
1869. "Hereditary Genius." London. 390 pp.
1883. "Inquiries into Human Faculty." London. 387 pp.

A. Gesell and H. Thompson
1929. "Learning and Growth in Identical Infant Twins," *Genet. Psych. Monog.*, 6, 1–124.

H. H. Goddard
1912. "The Kallikak Family." New York. 121 pp.

H. Gordon
1923. "Mental and Scholastic Tests among Retarded Children." London. 92 pp.

K. Gordon
1918–20. "The Influence of Heredity in Mental Ability," Children's Dept. Calif. State Board of Control, 4th. Bienn. Report.

H. Hart
1924. "Correlations between Intelligence Quotients of Siblings." *School and Society*, 20, 382.

J. D. Heilman
1928. "The Relative Influence upon Educational Achievement of Some Hereditary and Environmental Factors," *27th Yearbook N. S. S. E.*, II, 35–65.

G. Hildreth
1925. "The Resemblance of Siblings in Intelligence and Achievement," New York. 65 pp.

N. D. M. Hirsch
1930. "Twins, Heredity, and Environment," Cambridge. 149 pp.

K. Holzinger
1929. "The Relative Effect of Nature and Nurture Influences on Twin Differences," *Jour. Ed. Psych.*, 20, 241–248.

H. Jones
1928. "A First Study of Parent-child Resemblance in Intelligence," *27th Yearbook N. S. S. E.*, I, 61–73.

C. E. Lauterbach
1925. "Studies in Twin Resemblances," *Genetics*, 10, 525–569.

E. Lawrence
1932. "An Investigation into the Relation between Intelligence and Inheritance," *Brit. Jour. Psych. Monog. Suppl.*, No. 16, 80 pp.

A. M. Leahy
1932. "Selective Factors Influencing Prediction of Mental Ability of Adopted Children," *Jour. Genet. Psych.*, 40, 294–329.

C. Merriman
1924. "The Intellectual Resemblance of Twins," *Psych. Monog.*, 33: No. 5.

H. J. Muller
1925. "Mental Traits and Heredity," *Jour. Hered.*, 16, 433–448.

H. H. Newman
1929, 1932. "Mental and Physical Traits of Identical Twins Reared Apart," *Jour. Hered.*, 20; 23.

K. Pearson
1904. "On the Laws of Inheritance in Man. II. On the Inheritance of Mental and Moral Characters in Man," *Biometrika*, 3, 131–190.

G. E. Rensch
1921. "A Study of 365 Pairs of Siblings with Reference to the Influence of Heredity on Mental Ability," Stanford M.A. thesis, 35 pp.

Lois C. Strayer
1930. "Language and Growth: the Relative Efficacy of Early and Deferred Vocabulary Training, Studied by the Method of Co-twin Control," *Genet. Psych. Monog.*, 8, 209–319.

S. V. S. Theis
1924. "How Foster Children Turn Out," New York. 239 pp.

E. L. Thorndike
1928. "The Resemblance of Siblings in Intelligence," *27th Yearbook N. S. S. E.*, I, 41–53.

E. C. Tolman
1924. "The Inheritance of Maze-learning Ability in Rats," *Jour. Comp. Psych.*, 4, 1–18.

R. C. Tryon
1929. "The Genetics of Learning Ability in Rats—a Preliminary Report," *Univ. Calif. Publ. Psych.*, 4, 71–80. Also unpublished work.

R. R. Willoughby
1927. "Family Similarities in Mental-test Abilities," *Genet. Psych. Monog.*, 2, 235–277.

P. Wilson
1933. "A Study of Twins with Especial Reference to Heredity as a Factor in the Determination of Differences in Environment." In press.

A. H. Wingfield
1928. "Twins and Orphans: The Inheritance of Intelligence." London, 127 pp.

A. E. Winship
1900. "Jukes-Edwards: A Study in Education and Heredity." Harrisburg. 88 pp.

PALAMEDES[1]

DR. ALEXANDER WEINSTEIN
DEPARTMENT OF ZOOLOGY, THE JOHNS HOPKINS UNIVERSITY

THE advance of science, which formerly inspired mankind with confidence, has in recent years resulted in diffidence and even despair. In ancient times Archimedes could boast, "Give me where to stand and I will move the earth"; at the beginning of the modern era Francis Bacon took the whole world for his province. Newton's discoveries (so Halley said) raised man to the level of the gods; and subsequent discoveries raised him above divinity. Laplace found God an unnecessary hypothesis in astronomy, Lyell in geology, Darwin in biology. Thus the drama of Eden was reenacted on a larger stage and with the rôles reversed: God was banished from both heaven and earth, while Huxley remarked in a satanic and audible aside that man had created God in his own image, and Swinburne sang like an archangel:

> Glory to Man in the highest! for Man is the master of things.

There was, toward the end of the nineteenth century, a general impression that through science man had indeed conquered the external world and laid down its laws once and for all. There seemed nothing more to do but to turn science inward on ourselves; and that was what Galton proposed in his program of eugenics. The human species had outstripped all others in the evolutionary race; could it not go still farther? Could not men

> rise on stepping stones
> Of their dead selves to higher things?

Somehow this boasting is out of tune with the temper of to-day. The external world appears much more complicated than it did in the last century; and the founda-

[1] Paper read at the symposium of the American Society of Naturalists on "Heredity and Environment in Man," Atlantic City, December 30, 1932.

tions on which it rested so firmly are everywhere giving way beneath it. No longer do we stand firmly on the earth and raise our heads proudly among the stars; rather we totter precariously on shifting sands and peer tremulously into the darkness. Whether or not one shares this attitude, one can not help realizing its prevalence.

To the loss of self-confidence there have been three different reactions. One is an attempt to turn away from science and go back to a prescientific mode of living. This has been the program of the romanticists and the advocates of a simple life; of Samuel Butler in his proposal to abolish machines and of his numerous successors who cry out against the machine age of to-day. The suggestion has even been put forward that for a time we suspend research and take a holiday from science. This revolt against civilization has often been inspired by a love of nature, and there is something in it that would appeal to a society of naturalists; but on the whole it is of course an avoidance of the problem rather than a solution. A second proposal is to continue the scientific transformation of the environment to the utmost and so make the world a better place to live in. This is the solution most generally advocated, particularly by scientists, who have already done so much to transform the world. But even those who realize its necessity are beginning to doubt whether such a transformation is a sufficient solution of the problem. The human race, or at any rate a large part of it, seems incapable of coping with the complexities of the civilization which it has itself devised; how will it control a civilization still more complicated? There seems to be a real need for an increase in man's inborn capacities. Thus a third proposal is to adopt the program of eugenics; and even to those who are not entirely convinced of its necessity, the improvement of future generations has a moral and an esthetic appeal.

If we are to make a better breed of men, we must first decide what we mean by "better" and by "good." Thus

scientists found themselves confronted with a problem in ethics; this, too, at a time when they had been congratulating themselves on having finally and irrevocably banished from their outlook the moral considerations so common in ancient and medieval science. Moreover, the scientist could not, like the philosopher, approach the problem in leisurely fashion; he had to take it in his stride and solve it quickly as a mere preliminary to a problem of his own. A way out of the difficulty seemed to be indicated by a suggestion of Galton's: could we not discover the direction in which evolution is tending and accelerate its progress?[2] It appeared obvious that as evolution had transformed amoeba into man, so it would transform man into superman. To many it seemed obvious also that within the human species the victor in the evolutionary struggle was the white race: "Better fifty years of Europe than a cycle of Cathay." And within the white race the most successful were obviously the upper classes. If we selected from these we should be helping evolution along—giving the inevitable a shove in the right direction.

But the inevitable refused to be shoved. The upper classes, far from supplanting the others, were themselves found to be dying out because of their low birth rate. It was even said that the very existence of the white race was threatened by the prolificity of others; and while politicians spoke of the yellow peril there was talk in biological circles of the rising tide of color. The logical conclusion from all this was of course that the white race and particularly its upper classes are not the fittest in an evolutionary sense; but this conclusion was distasteful to the eugenists, who were themselves largely upper-class whites. They decided instead that the law of the survival of the fittest was being broken and began to cry aloud for its enforcement: they wanted conditions made such that the existence of the upper classes would be guaranteed.

[2] Francis Galton, "Inquiries into Human Faculty," London, 1883, p. 304.

Whatever we may think of such a procedure, its justification is no longer in evolution but in our own preferences; and if our preferences are to have any objective validity, we must be certain first that race and class differences are genetic, and second that the qualities we prefer are really superior.

The hypothesis that all race and class differences are genetic is often based on views attributed to Galton; it is commonly believed that as a result of his researches he came to the conclusion that nature prevails enormously over nurture. Most biologists would probably consider it a travesty to say that what Galton proved was that differences in heredity are more potent than differences in environment when the differences in environment are not too great; but that is the meaning of Galton's own summaries of his results. "The evidence was overwhelming that the power of nature was far stronger than that of nurture, when the nurtures of the persons compared were not exceedingly different." "There is no escape from the conclusion that nature prevails enormously over nurture when the differences of nurture do not exceed what is commonly to be found among persons of the same rank of society and in the same country."[3] Obviously this does not mean that environmental differences between races or classes can be neglected.

Galton himself believed that the environment affects many traits:

> Different aspects of the multifarious character of man respond to different calls from without, so that the same individual, and, much more, the same race, may behave very differently at different epochs. There may have been no fundamental change of character, but a different phase or mood of it may have been evoked by special circumstances, or those persons in whom that mood is naturally dominant may through some accident have the opportunity of acting for the time as representatives of the race. . . . Sudden eras of great intellectual progress can not be due to any alteration in the natural faculties of the race, because there has not been time for that, but to their being directed in productive channels.[4]

[3] Francis Galton, "Memories of My Life," London, 1908, pp. 294–295. "Inquiries into Human Faculty," p. 241.

[4] Francis Galton, "Inquiries into Human Faculty," pp. 178, 179.

It is often said that savages differ fundamentally from civilized peoples in being conservative and unenterprising. Even this difference Galton explained environmentally. To a civilized man, he said, change is easy because of the abundance of his material resources; whereas to a savage, whose resources are small, change is difficult so that "he is perforce taught to be conservative, his ideas are fixed, and he becomes scandalized even at the suggestion of change."[5]

Differences within the same race and social class were also attributed by Galton to environment. He thought that it was "owing to the favourable conditions of their early training, that an unusually large proportion of the sons of the most gifted men of science become distinguished in the same career."[6] He ascribed the choice of a scientific or of a church career to the influence of the mother in early childhood. Galton held such strong views on the persistence of childhood impressions that it is surprising he has not been adopted by the Freudians.

> The furniture of a man's mind [he wrote] chiefly consists of his recollections and the bonds that unite them. As all this is the fruit of experience, it must differ greatly in different minds according to their individual experiences. I have endeavoured to take stock of my own mental furniture in the way described in the next chapter, in which it will be seen how large a part consists of childish recollections, testifying to the permanent effect of many of the results of early education. The same fact has been strongly brought out by the replies from correspondents whom I had questioned on their mental imagery. It was frequently stated that the mental image invariably evoked by certain words was some event of childish experience or fancy. . . .
> Our abstract ideas being mostly drawn from external experiences, their character also must depend upon the events of our individual histories. . . . The character of our abstract ideas, therefore, depends, to a considerable degree, on our nurture.[7]

I have quoted Galton in some detail because he is generally misrepresented, and because his views, while not necessarily correct, were based on a careful and penetrating examination of much evidence. Occasion-

[5] *Ibid.*, p. 180.

[6] Francis Galton, "Hereditary Genius," p. 197, London, 1869.

[7] Francis Galton, "Inquiries into Human Faculty," pp. 182–183.

ally, it is true, his words can be interpreted to mean that the power of heredity is overwhelming and the influence of environment negligible; but only, I think, because he has neglected to say explicitly that he is speaking not of environment in general, but of "Nurture within the limited range that I have been careful to assign to the latter."[8]

Galton's successors, the biometricians, have found that the extent to which a character is correlated with the same character in related individuals is often greater than the extent to which it is correlated with some aspect of the environment. These correlations however do not necessarily measure the strength of heredity and of environment respectively. On the one hand, the similarity of related individuals may be due to environment, as in language or in infectious or nutritional diseases. On the other hand, the fact that a character is independent of some aspects of the environment does not demonstrate its independence of other aspects. Moreover, the correlations worked out were not very numerous, certainly not numerous enough to warrant a generalization as to the stability of all characters.

The last difficulty was apparently met by Mendelian studies; for of the numerous traits found to be inherited in Mendelian fashion, relatively few were influenced by environment. The traits studied however, although numerous, are not representative: they are used as indicators of the presence of genes; and traits that vary with environment, being poor indicators, are discarded as bad characters. It is because geneticists have concerned themselves mostly with constant traits that the traits they have studied have turned out to be constant. This is not the first time that scientists have mistaken limitations arbitrarily imposed by themselves for laws of nature.

Despite the unrepresentative character of the material, many Mendelian traits have been found which are

[8] *Ibid.*, p. 235.

affected by environment as much as by heredity, or even more; a result borne out by the differences observed by Professor Muller and Professor Newman in identical twins reared apart. Physiologists also have discovered many differences in growth, development and behavior produced by small and hitherto unsuspected differences in food, air or sunlight. Professor Pavlov found his experimental animals sensitive to minute stimuli. The "slightest movements [of the experimenter]—blinking of the eyelids or movement of the eyes, posture, respiration and so on—all acted as stimuli which, falling upon the dog, were sufficient to vitiate the experiments by making exact interpretation of the results extremely difficult . . . the experimenter . . . had to be stationed outside the room in which the dog was placed, and even this precaution proved unsuccessful in laboratories not specially designed for the study of these particular reflexes. . . . To get over all these disturbing factors a special laboratory was built. . . ."[9]

Such precautions are taken as a matter of course in experiments with animals. Yet, although man's behavior is known to be more modifiable than that of other species, it is often assumed to be unaffected by the conditions under which different races or classes live. A prominent psychologist who tried to test the ingenuity of cats by using hunger as a stimulus was criticized for basing conclusions about cats in general on hungry specimens. Many eugenists however write as if the educability of poor children is not influenced by lack of food.

There is a wide-spread belief that races differ greatly in mental capacity and that the differences are genetic. Both of these propositions are open to serious doubt. It is true that peoples may be very dissimilar in what they attend to or how they express themselves or how they behave; but when the thought processes underlying these diverse activities are examined, they are found to be essentially alike. The general impression that savages

[9] I. P. Pavlov, "Conditioned Reflexes," Oxford, 1927, p. 20.

are unreasonable is due to a lack of acquaintance with their motives; for the civilized men who visit savages or live among them are generally ignorant of their language and customs. It is notorious that travelers often give very erroneous impressions of the customs and ideas even of civilized nations closely related to their own.

Even knowledge, however, is not a guaranty against prejudice; and it is well to remember the words written by Herodotus some 2,400 years ago:

> If it were proposed to all nations to choose which seemed best of all customs, each, after examination made, would place its own first; so well is each persuaded that its own are by far the best.[10]

Galton, despite his realization of the importance of environment, nevertheless attributed to heredity many racial differences in mentality; and he argued for the superiority of the white over savage races. He adduced however no cogent evidence for these views, and sometimes his statements are curiously naive. "It is seldom," he wrote, "that we hear of a white traveller meeting with a black chief whom he feels to be the better man."[11] Travelers are not noted for any tendency to admit their inferiority to the people among whom they travel, and they would scarcely be likely to make an exception in favor of savages. Moreover, a traveler who is not a better man than the chiefs he visits might never return to tell any tale at all.

So similar are the essential thought processes of savages and civilized peoples that anthropological accounts often read like travesties of civilized customs; this in fact explains much of the charm of anthropological literature and why among laymen anthropology is one of the most popular sciences. And (to put the shoe on the other foot) satirists have never had any difficulty in rendering civilization ludicrous by merely describing without comment the actions of civilized nations.

[10] Herodotus, Book 3, Chapter 38. The translation quoted is that of A. D. Godley (Loeb Classical Library).

[11] Francis Galton, "Hereditary Genius," p. 339.

It is sometimes said that savage races would have achieved civilization if they had been capable of it. To substantiate such an argument, however, we should have to know why they did not achieve it and why we did; and this would require a far greater knowledge of the processes of cultural history than we possess. It is significant in this connection that even races often considered savage have made great cultural achievements (for example the Maya Indians, who developed a system of writing and a calendar superior to the European calendar of the time); that races once civilized have sunk to a lower stage of culture; and that the relative cultural standing of peoples has often changed in the course of history.

Comparisons have also been made between different races living together; for example, Negroes and whites in the United States. But these races are far from having the same environment. The housing and hygienic conditions and the educational facilities of the Negroes are much inferior to those of the whites; and there are besides the dissimilarities in tradition and the effects of race prejudice. To disregard environment in such comparisons is to shut one's eyes to plain facts. Some psychologists have attempted to devise mental tests that would measure only genetic traits; but attempts of this kind are futile, for no traits are purely genetic and mental traits in particular are susceptible to environmental influences. Professor Garth, who says that "his first investigations in the field of race psychology were accompanied by a silent conviction that he would find clear cut racial differences in mental processes," finally concluded, on the basis of his own work and that of others, that "we have never, with all our searching, found indisputable evidence for belief in mental differences which are essentially racial."[12]

It might be considered unlikely that evolution should have produced morphological racial differences without

[12] T. R. Garth, "Racial Psychology," New York, 1932, pp. vii, 24.

having produced psychological ones as well. It is true that the observed structural differences between races are not known to influence mentality; but surely there must be others that do. The argument however overlooks an essential distinction. Physical traits, if unimportant, will vary at random, unchecked by natural selection; and if important will vary by becoming adapted to different environments through natural selection. Mentality, however, being important, will not vary at random; in all environments it will tend, through natural selection, to become rational and hence uniform; for logic is logic from China to Peru and from Greenland's icy mountains to India's coral strand.

Even if evolution in the past had separated out diverse mental types, we should scarcely expect to find such differences characterizing large groups to-day; for throughout history there has been a continual mixture of races. In the oldest civilization known, that of Egypt, there was in the nineteenth century B. C. a royal edict against the coming of Negroes down the Nile. Wherever there is a prohibition there must be something to prohibit; and we can draw the conclusion that Negroes must have entered Egypt before the edict and probably after. In fact the very Pharaoh who issued the law boasted in another inscription that he had raided the lands of the Negroes and carried off their women.[13] In the next oldest civilization known, that of Mesopotamia, we find at the opening of history at least two different races and probably more. The same is true of China, of Greece and of Italy. Early in her history Rome was invaded by barbarians from the north; and this continued with relatively slight intermissions until her fall. Even when there were no invasions, there was a continual importation of slaves from many other lands. In prehistoric times and throughout history migrations and wars, exploration, commerce and slavery have trans-

[13] J. H. Breasted, "Records of Ancient Egypt," 1906, vol. 1, paragraphs 652, 658.

ported large numbers of people and often entire nations across all natural barriers. In view of facts like these, claims to racial purity on the part of nations are without genetic value. So-called national characteristics are much more likely to have their origin in environment or tradition than in hereditary constitution; they are perhaps still more likely to be inventions of historians.

The decline of nations is often attributed to an influx of alien blood. This argument has been applied particularly to Rome; but as a matter of fact much of Rome's greatness was due to foreigners. Her earliest writers were Greek slaves; her last great writer, Claudian, an Egyptian. Terence was a Carthaginian slave; Catullus and Livy came from Cisalpine Gaul; Seneca, Lucan, Martial from Spain. Of Roman poets perhaps the most typical were Virgil and Horace. Yet Virgil is not known to have had any Roman blood: he came from beyond the Po and was legally a Gaul until after he had attained manhood, when his province was enfranchised. Horace was not of Roman ancestry at all, as he was born in southern Italy, the son of an emancipated slave. When all roads lead to Rome, the able and ambitious tend to congregate there. Smaller communities also owe much to foreigners. Galton wrote: "It is very remarkable how large a proportion of the eminent men of all countries bear foreign names, and are the children of political refugees,—men well qualified to introduce a valuable strain of blood."[14] It would, I think, be nearer the truth to ascribe the greatness of nations rather than their decline to foreigners.

These facts militate strongly against the oft-repeated assertion that race mixture in itself produces degeneration. Such a result would be expected on genetic theory only in special cases; race mixture in general should produce new combinations of genes, some doubtless worse but others even better than the original ones.

[14] Francis Galton, "Hereditary Genius," p. 360.

Differences between classes are not so great as those between races; but they have been more minutely studied because they are of great practical importance. There are many persons, such as society leaders, editors of society columns, butlers, footmen, hotel clerks, and shopkeepers, who are as expert at distinguishing classes as anthropologists are at distinguishing races. Class distinctions, moreover, have been popularized by novelists. The aristocrat is proverbially tall, thin, and handsome. In England he used to have a dark complexion—a mark of his Norman blood; but this may now be altered by the popularity of the Nordic theory. He is well-dressed and has a characteristic manner; he is more sensitive than other people; he is interested in war and hunting. I am not aware that these distinctions have ever been studied statistically but they are generally supposed to be valid.

It used to be widely believed that a person of gentle blood could be recognized as such even if unaware of his ancestry and brought up among peasants and slaves. Herodotus tells such a story about Cyrus, king of the Persians; and many romances have turned on the same theme. I know of no experimental evidence that the distinctions are really genetic, unless we accept Hans Christian Andersen's account of the princess who was recognized as of royal blood because she was sensitive enough to feel a pea through a thickness of twenty mattresses and twenty featherbeds. There is, however, evidence against the genetic view of class distinctions. In Tudor England the costume of every social class, from nobility to laborers, was minutely regulated by law; and in colonial Virginia the lower classes were forbidden to dress too well, presumably lest they be mistaken for gentry. We know now that physical traits can be affected by nutrition and hygiene, and behavior by governesses and finishing schools; and our dictionaries define "breeding" as "the result of training." Nevertheless, the belief in the genetic nature of class distinctions has been

held even by scientific men; and a German gynecologist has asserted that while the sexual impulse is instinctive in women of the lower classes it is acquired in those of the upper classes.

Such beliefs have waned with the spread of democracy; but even in democratic countries it is still said that the upper classes are abler and more intelligent than the lower, that they alone know how to govern, that from their ranks come the great artists and writers and scientists. If a poor man becomes famous, the genealogists immediately begin to look for forgotten or illegitimate ancestors; a familiar instance is the attempt to trace Lincoln's pedigree to Chief Justice Marshall. What used to be considered romance now passes for eugenics.

It is of course true that the richer classes have contributed proportionally a greater number of eminent men than have the poor. But this is due in part at least to their better opportunities and there is no evidence that it is due to anything else. In a country like ours, where we hear equality spoken of so often, we come to believe that rich and poor have essentially the same chance of success. The belief is facilitated by the fact that rich and poor rarely know each other's life with any intimacy; hence the rich do not realize the obstacles confronting a poor man who would undertake an intellectual career, and the poor do not realize the extent to which these obstacles would disappear in an environment of wealth. The misunderstanding is increased by the fact that very few people of any class have an adequate comprehension of the psychology of creative intellectual work. There is a wide-spread notion that great ideas come as inspirations and that their coming can not be controlled or even predicted. It is true that great ideas often come at unexpected moments; but I doubt whether they ever come without preparation. They are the result of long intensive work, of complete absorption in a subject. Often the idea does not come until after the worker has rested from his labor; and this inactive period is probably the

source of the opinion that labor is unnecessary. Now, obviously, complete absorption in a subject is possible only where there is leisure; and this means that it is all but impossible for a really poor man, who has no leisure, to do great creative work. The sciences are now so complicated that years of preparation are required even to understand the important problems, and often years more of steady work for any solution.

In the arts the situation is often considered different. But although poets are born they must also be made, or at least they must not be unmade. Let me quote in this connection a passage from Sir Arthur Quiller-Couch:

> What are the great poetical names of the last hundred years or so? Coleridge, Wordsworth, Byron, Shelley, Landor, Keats, Tennyson, Browning, Arnold, Morris, Rossetti, Swinburne—we may stop there. Of these, all but Keats, Browning, Rossetti were university men; and of these three Keats, who died young, cut off in his prime, was the only one not fairly well-to-do. It may seem a brutal thing to say, and it is a sad thing to say: but, as a matter of hard fact, the theory that poetical genius bloweth where it listeth, and equally in poor and rich, holds little truth. As a matter of hard fact, nine out of those twelve were university men; which means that somehow or other they procured the means to get the best education England can give. As a matter of hard fact, of the remaining three you know that Browning was well-to-do, and I challenge you that, if he had not been well-to-do, he would no more have attained to writing *Saul* or *The Ring and the Book* than Ruskin would have attained to writing *Modern Painters* if his father had not dealt prosperously in business. Rossetti had a small private income; and, moreover, he painted. There remains but Keats; whom Atropos slew young, as she slew John Clare in a madhouse, and James Thomson by the laudanum he took to drug disappointment. These are dreadful facts, but let us face them. It is—however dishonouring to us as a nation—certain that, by some fault in our commonwealth, the poor poet has not in these days, nor has had for two hundred years, a dog's chance. Believe me—and I have spent a great part of the last ten years in watching some 320 elementary schools—we may prate of democracy, but actually a poor child in England has little more hope than had the son of an Athenian slave to be emancipated into that intellectual freedom of which great writings are born.[15]

This is the statement not of a politician or a propagandist but of the King Edward VII professor of English literature at the University of Cambridge.

[15] Arthur Quiller-Couch, "On the Art of Writing," New York, 1916, pp. 46–47.

There is a wide-spread notion that the really able will succeed, despite all obstacles. This involves a statistical fallacy: it might under certain circumstances be true if our lives were indefinitely long, but it does not apply to finite lifetimes. There is also a confusion between the fate of an idea and of its advocates. A true idea is perhaps bound to survive; but so far is this from applying to its discoverers or supporters that the best way to insure the survival of an idea is to undergo martyrdom for its sake.

Another common belief, expressed by Galton and others, is that the best strains of the lower classes have been drained into the upper classes. This involves two separate propositions: (1) that people have risen in the social scale, (2) that those who have risen are the most desirable. The first proposition is true, although it must not be forgotten that in the past the surmounting of class barriers has often been difficult or impossible. The second proposition is usually treated as self-evident; to most people it seems obvious that economic success depends upon intellectual ability. Thus a well-known eugenist said twenty years ago that good workingmen do not lose their jobs, that only incompetent men are unemployed. This showed a lack of historical knowledge, for economic conditions have in the past caused wide-spread unemployment. Only recently, however, another prominent eugenist said that the present depression would have a good effect by weeding out the unfit.

Now in spite of the fact that in times like the present the economic system picks largely at random, it may well be that at other times the people who became rich were selected to some extent at least on the basis of genetic traits. But are these traits the desirable ones? They have not always been so considered. The aristocratic classes have always looked down on those who become wealthy through their own efforts. The Catholic Church, in the middle ages and during the reformation, objected

to the ordinary practises involved in business, such as lending money at interest; so, too, did Luther and other Protestant leaders. Modern liberals and radicals echo these objections, or carry them to their logical conclusion as in Proudhon's statement that "property is theft." Such views have received some support from Francis Galton, who in his "Memories" expressed a fear that marriages of English peers with daughters of millionaires might result in a lowering of the standards of commercial probity of the House of Lords in future generations. He might have added that many of the newer peerages have been conferred for success in business and many older peerages for services that can not be considered honest.

Francis Bacon, who was a man of wide experience and neither a visionary nor a radical, said that "there is rarely any rising but by a commixture of good and evil arts";[16] a very mild opinion in comparison with that of Machiavelli, who had already explained how to rise without recourse to good arts at all. Machiavelli's ideas have been denounced ever since they were published but only, I think, because they gave away the game; they have never been refuted, and the "Prince" is still the best handbook for getting along in the world. Plato and Machiavelli are not usually bracketed together; but a passage in the "Republic" says that if there should ever be a perfectly just man, he would be crucified; while a perfectly unjust man would be successful in all his affairs, would be able to marry his children to whomever he pleased, and through his great riches could even propitiate heaven with splendid sacrifices, so that a better provision is made by both gods and men for the life of the unjust than for the life of the just. This passage reads as if it had been inspired by the fate of Socrates. The spectacle of Truth forever on the scaffold, Wrong

[16] Francis Bacon, "Essays. Of Nobility."

forever on the throne has brought about the widely prevalent sympathy with martyrdom, and has been a powerful influence in the spread of Christianity.

Some eugenists, admitting that success often results from non-conformity to accepted moral standards, have concluded that the standards should be changed. They have advocated selfishness and ruthlessness, have justified war, and have proposed to breed a race devoid of kindness and sympathy. Such a code is not debatable if it is put forward as good in itself. If however the code is advocated as a means to ends which are generally considered good, then I think the arguments for it can be shown to be incorrect; if indeed a logical demonstration is still needed when the results of selfishness are evident all about us. Among eugenists the usual justification of selfish competition is that it has been responsible for evolutionary progress. But we are not bound by evolutionary precedents; and if there is anything that evolution teaches it is the possibility of new modes of behavior. Kindness and cooperation however are not new: they were developed (as Darwin pointed out) in the struggle for existence and helped man to survive and advance in prehistoric times. Some eugenists base their codes on the behavior of other species; but even if we agreed to imitate other organisms, we could still justify almost any code we pleased by selecting the proper model: we could go to the ant, or consider the lilies of the field.

Many who admit that success does not imply ethical conduct maintain nevertheless that it does imply intelligence. For example, Mr. Edgar Schuster, who was the first research fellow of the Galton Eugenics Laboratory, wrote:

> It may be that the opportunities sometimes favour moral attributes of an anti-social kind, but they never favour a weak intellect; the predatory millionaire is perhaps ethically of the same standing as the burglar, but intellectually he far surpasses him.[17]

[17] Edgar Schuster, "Eugenics." Baltimore, 1912, p. 225.

If the intelligent and the dishonest have both been rising to the upper classes, the resulting intermarriages between them must have produced a tendency for the two traits to be associated. This would explain many of the ills of society. But it is doubtful whether the tendency is general, because the amount of intelligence required for rising in the social scale is not necessarily great, and in many situations too much intelligence is an impediment. At a convention of business men some years ago an executive said that although every one laments the lack of able assistants, yet any man who turns out to be unusually intelligent is certain to be discharged because his superiors are afraid of being supplanted by him. In politics, too, intelligence (beyond a certain modicum) is a drawback. The best-known example is the American presidency. It has been often remarked that a first-rate man rarely obtains his party's nomination and that presidential candidates are usually selected from among the less able contenders. The intelligent are always looked at askance; it is no compliment to a man to say that he lives by his wits.

The aristocracy have often been undoubtedly inferior to many members of the lower classes. In ancient Rome many of the slaves had been men of high social standing in their original homes and were better educated than their masters; in fact the earliest Roman intelligentsia was composed very largely of Greek slaves. The medieval barons looked down on those who could read and write.

Class distinctions have in fact been based largely on irrational grounds. The social esteem in which traits are held is often in inverse proportion to their intrinsic or social value. Manual labor is almost universally despised; and this has been carried so far that even scientific experimentation and artistic activity have been considered degrading. Plato objected to the introduction

of mechanical methods into geometry;[18] Archimedes considered his mechanical inventions unworthy of a scientist; and Lucian complained that even great sculptors were held in scorn.

> You may turn out a Pheidias or a Polycleitus, to be sure, and create a number of wonderful works; but even so, though your art will be generally commended, no sensible observer will be found to wish himself like you; whatever your real qualities, you will always rank as a common craftsman who makes his living with his hands.[19]

Nor have class distinctions always been consistent. In ancient Greece actors might enjoy high social status, take an important part in the politics of their communities, and associate with kings. Shakespeare, as an actor, had in the eyes of the law the choice of becoming a retainer to a nobleman or being classed as a rogue and vagabond. Molière as an actor was not eligible for Christian burial. To-day actors may be knighted and actresses may marry noblemen or millionaires. When, in addition, we consider how much change in social position has resulted from causes beyond the control of single individuals (enslavement of prisoners of war, economic changes, etc.) it would be strange if class lines corresponded to genetic distinctions.

The strengthening of class barriers, which has been advocated by many eugenists, would therefore be eugenically useless and even harmful. For in so far as class distinctions are environmental, they make genetic differences harder to recognize; and in so far as they are genetic, the best qualities are not necessarily in the upper classes and there is even evidence that the reverse may be the case. It is a curious episode in the history of science that eugenists should have defended class distinctions; it is still more curious that they should have

[18] But of course it is true that mechanical methods are not a substitute for logical proof.

[19] Lucian, "The Vision," chapter 9. The translation is that of H. W. and F. G. Fowler, Oxford, 1905.

done so in the name of Galton. For Galton stated very emphatically the anti-eugenic effects of inherited wealth:

> The sickly children of a wealthy family have a better chance of living and rearing offspring than the stalwart children of a poor one. As with the body, so with the mind. Poverty is more adverse to early marriages than is natural bad temper, or inferiority of intellect. In civilized society, money interposes her aegis between the law of natural selection and very many of its rightful victims. Scrofula and madness are naturalized among us by wealth; short-sightedness is becoming so. There seems no limit to the morbific tendencies of body or mind that might accumulate in a land where the law of primogeniture was general, and where riches were more esteemed than personal qualities.[20]

> The best form of civilization in respect to the improvement of the race, would be one in which society was not costly; where incomes were chiefly derived from professional sources, and not much through inheritance; where every lad had a chance of showing his abilities, and, if highly gifted, was enabled to achieve a first-class education and entrance into professional life, by the liberal help of the exhibitions and scholarships which he had gained in his early youth. . . .[21]

Darwin and Huxley realized that wealth might suspend or reverse natural selection. In Plato's eugenic commonwealth there was to be neither excessive riches nor poverty for ordinary citizens, and for superior individuals no private property at all. A still earlier eugenist, Theognis of Megara, who was like Plato of aristocratic family, explained that poverty led to race-degeneration by forcing people to marry for money instead of for good genetic qualities.[22]

Even professed egalitarians do not always realize how thorough an equality of opportunity is required as a basis for eugenics. It is not enough (in the words of Anatole France) to "forbid rich and poor alike to sleep under the bridges." There must be freedom of opportunity for all, and that too at all ages; because desirable qualities may manifest themselves at various periods of life. Even apart from any eugenic application, this is

[20] Francis Galton, "Hereditary Talent and Character," *Macmillan's Magazine*, vol. 12, p. 326 (1865).

[21] Francis Galton, "Hereditary Genius," p. 362.

[22] Theognis, "Elegies," ll. 183–196.

the only way in which man's genetic qualities can be studied; and geneticists should have the less hesitation in advocating it because they can shift the actual execution onto the shoulders of economists. All this however is only preliminary; there remains a much more difficult question: who is to recognize the superior individuals and select them for propagation?

This question has never been properly answered. Some have envisaged a system of eugenic committees elected democratically; but the failure of democracies to pick superior individuals would make this worse than useless. Many eugenists have turned to aristocracy. It should not be forgotten, however, that aristocracy has had its opportunity and failed more miserably than democracy. If we consider the politicians of the past whom we might be tempted to entrust with a scientific task, we can scarcely select one more enlightened than Francis Bacon. He was a scholar and a philosopher, an advocate of the experimental method and of the founding of scientific societies. In his time the greatest scientific advances were those connected with astronomy; yet he did not appreciate the work of Kepler or Galileo, who were his contemporaries, or even of Copernicus, who lived two generations earlier. William Harvey, who was his personal physician, said that Bacon wrote science like a lord chancellor; and I am afraid that any future lord chancellor is likely to write it in the same way.

The distrust of politicians has caused many to turn to non-political intellectuals. We have such a body in the electors of the Hall of Fame, who are entrusted with the task of drawing up a roll of honor of the country's most illustrious dead. Their decisions show the same preference for mediocrity: Willard Gibbs, generally accounted America's greatest scientist, has never been elected; Edgar Allan Poe, generally regarded as America's greatest man of letters, was not chosen until after many inferior writers.

But (you will say) it would be too much to expect all the electors to be well versed in thermodynamics or even in the principles of literary criticism; why not have experts in each field pick their own geniuses? That too has been tried. Perhaps the most famous body of experts among intellectuals is the Académie Française. I will refrain from reading you a list of the mediocrities whom it has honored with membership; but among those who have failed of election are Descartes, Pascal, Molière, LeSage, Diderot, Rousseau, Beaumarchais, André Chénier, Comte, Balzac, Stendhal, Dumas père, Gautier, Michelet, Flaubert, Maupassant, Daudet, Zola, Verlaine, Baudelaire, and many others. The Academy has excluded France's greatest philosophers, her greatest novelists, her greatest dramatist, and some of her greatest historians and poets. In artistic and literary competitions the prize is usually awarded to mediocre work; a fact so well known that it led eminent literary men to object to a recent proposal that the League of Nations establish prizes for the encouragement of young writers and artists.

The great scientific societies, which were orginally founded to help the active prosecution of research, have come to confine themselves largely to honoring men who no longer do research. How far out of touch they are with important scientific developments is sometimes shown strikingly as in the rejection of Joule's paper by the Royal Society.

The record of universities is no better. After Plato's death the headship of the Academy fell not to Aristotle or to Heracleides of Pontus, but to mediocre men—Speusippus and Xenocrates. It is interesting in this connection that while Aristotle wrote, "Plato is dear but truth is dearer," Speusippus (who was Plato's nephew) spread the story that Plato was the son not of a mortal father but of Apollo. Modern universities were not hospitable to science when it began the advances that

have transformed civilization; that is why scientific societies were founded. "Neither Copernicus, nor Bacon, nor Boyle, nor Huygens, nor Leeuwenhoek, nor Swammerdam, nor Van Helmont, nor Kepler, nor Guericke, nor Fermat, nor Napier, nor Stevin, nor Pascal, nor Descartes ever taught at any school or university."[23] The universities have not even pretended to encourage literature. In Shakespeare's day, Oxford had so low an opinion of contemporary drama that the university authorities regularly paid visiting dramatic companies to depart without presenting any plays. When the third folio of Shakespeare's works was published, the Bodleian library at Oxford sold its only copy of the first folio, with other superfluous books, for £24, to repurchase it in 1905 for £3000. Shakespeare of course was not an Oxford man; but Oxford has had two great poets among her students. Of these Shelley was expelled; and Swinburne was quietly asked to leave, escaping expulsion only because his college feared to make itself ridiculous by a repetition of the Shelley episode.

To-day also unusual ability and originality fail to obtain recognition at universities: sometimes despite the most careful and conscientious attempts to discover them. This is illustrated by the wranglerships at Cambridge. Until recently all graduating students in mathematics were arranged in order of their success in the examinations, and it has been noticed that while the top man (Senior Wrangler) rarely became a great scientist the Second Wranglers have contributed many of Cambridge's greatest mathematicians and physicists. It is obvious that the examiners did not know how to test for great originality. Whatever the reason, it is a well-known fact that most teachers prefer students who merely follow in their footsteps to those who strike out new paths. It is rare for a university appointment to go to

[23] Preserved Smith, "History of Modern Culture," New York, 1930, pp. 343–344.

the logical candidate; usually the choice falls on some one less able. It is the fashion to blame this state of affairs on the autocratic interference of university presidents and trustees; but the great majority of selections are made by the faculty themselves and by the department concerned.

This regression toward inferiority is brought about by several causes. There is an economic factor. An associate or subordinate is often a competitor or a potential competitor for position or patronage, and to raise up an able rival involves an unnecessary risk. Sometimes the rivalry is personal. People wish to tower above their fellows; and if they can do it in no other way they can at least stand out because of the flatness of the surrounding country. This fact is very important because the great majority of people are lacking in altruism. A third cause is the difficulty of recognizing great achievements. We judge people by what intellectual standards we have; but the greatest men are those who transcend or overthrow old standards and set up new ones. They can not be judged until after their standards have been accepted; hence as long as there is intellectual advance the leaders of it will be misunderstood or not understood at all. A fourth cause is that great men may fail to accomplish anything commensurate with their ability. They attempt more tasks and greater tasks and on a grander scale. On the other hand, a mediocre man who merely follows in the footsteps of others is fairly certain to accomplish something and to be appreciated. Those who have undertaken great quests have often met with frustration; while many a man who has started out to seek his father's asses has found a kingdom.

The regularity and inevitability with which these forces work is not usually realized by those unfamiliar with the history of thought. Let us consider, for example, our own science of genetics, limiting ourselves, for obvious reasons, to geneticists of the past. Of these, none have

contributed more than Mendel, Darwin, Galton, and Bateson. Mendel discovered the laws of heredity when they were being sought by many of the world's greatest biologists: but no one paid any attention to his discovery. He corresponded with Naegeli, one of the foremost authorities on the subject, and sent him seeds; yet Naegeli, although he wrote a treatise on heredity, did not so much as mention Mendel's work. Mendel failed even to obtain a regular teaching position at a gymnasium, although his students have testified that he was an unusually good teacher.

Darwin did not distinguish himself at school, or at the Universities of Edinburgh and Cambridge, Britain's foremost medical and scientific institutions. Neither he nor Galton, who also went to Cambridge, took a degree with honors, which a moderately clever undergraduate can do; and according to Galton some of the ablest undergraduates of his time failed to take honors. It is an interesting speculation what would have happened to Darwin and Galton if they had not been rich, or to Bateson if his father had not been master of St. John's College at Cambridge; for the headmaster of Bateson's school wrote to his father: "It is very doubtful whether so vague and aimless a boy will profit by University life."[24] I think we may safely conclude that it takes a genius to catch a genius.

But, as I have said, genius is not enough.[25] What is needed is not only intelligence but goodness as well; and unfortunately there is no evidence that the two are positively correlated. In some situations, in fact, the correlation is negative: an intelligent judge is more likely to recognize ability in others, but for this very reason is more likely to be jealous.

[24] William Bateson, F.R.S., Naturalist, edited by Beatrice Bateson, Cambridge, 1928, p. 8.

[25] We need only recall, for example, Humphry Davy's opposition to Faraday's election to the Royal Society.

If those entrusted with a eugenic program are not good, it is better that they should not be intelligent either; for if they are intelligent they can recognize merit more easily and weed it out more certainly. Eugenics therefore is driven to a conclusion reached by all the great moralists: that the immediate need of the world is good men. Moralists, however, have made two great mistakes: they have attempted to base morality on theological sanctions, and they have tried to inculcate it by teaching. The first error has been often exposed; but the possibility of teaching virtue is still almost universally believed in, although I doubt whether history records a single instance of a real alteration in a person's moral quality. The constancy of moral traits may appear incompatible with the modifiability of other mental traits by environmental influences. I do not, however, claim that moral traits will remain constant under all circumstances whatsoever; it may be that some day goodness will be induced by vaccination or by injection. But the incentives to a moral life have not been essentially altered by social and economic changes in the past, and they are not likely to be altered by any changes that have been proposed for the future. If private property is abolished, men will still want power; if power is abolished (but that will be difficult) men will still want the approbation and esteem of their fellows. Even the greatest men have lapsed from honesty in order to enhance their reputations still further. So strong is the urge, that in order to be considered wise, men will act stupidly; and in order to be considered good, they will break every principle of morality.

Galton thought that eugenics might succeed if it became a religion; but the history of religious institutions reveals the same tendency to suppress merit as is found elsewhere. In the elections of popes, as in the nominations of American presidents, the leading candidate is rarely chosen. Religion has encouraged hypocrisy and

has persecuted, imprisoned, tortured and killed men of independent mind; and Galton himself pointed out that in this way the genetic qualities of the human race have been greatly impaired.

The religion advocated by Galton was not theology, but a sense of obligation to one's fellow-men combined with an emotional fervor. Such an attitude is found in some types of patriotism (though not in all). Yet even when a nation is in danger, politicians and military men continue their usual intrigues, often in accentuated form; while in ordinary individuals a national crisis such as war evokes the worst instincts.

It might be objected that in patriotism there is an irrational factor that would be absent in a scientific gospel. Let us therefore examine science itself, which often inspires a feeling of duty to mankind, including future generations. Despite this, scientists are not (except in the minds of innocent laymen) unselfish individuals; it is a very exceptional scientist who will not sacrifice the future of science to his own personal interests.

The betrayal of science is facilitated by the very faith it inspires; any setback it receives is regarded as temporary because of the wide-spread notion that in the end truth will prevail. A setback for eugenics, however, involving the extinction of valuable strains, might be irreparable. For this reason, and because it deals with man and what may be considered man's essential nature—his genetic constitution—eugenics might be expected to inspire a more intense devotion. The eugenic movement has in fact taken on a religious fervor, as Galton hoped; but I can not believe that he would have approved either the ideals or the methods advocated by most eugenists. He stood for intellectual and moral enlightenment and for social justice; he looked upon eugenics as a method of doing away with the cruelty of natural selection. Many of those who speak in his name have advocated racial and religious prejudice and economic and political

oppression. They have sought to furnish a quasi-scientific foundation for political reaction, especially in Germany; and in the United States their pronouncements are not easily distinguishable from those of the Ku Klux Klan.

There remains Galton's other suggestion, already alluded to, that we ascertain whither evolution is going and hasten its progress. This is tantamount to a deification of evolution, at any rate if God is defined (in the words of Matthew Arnold) as "a force, not ourselves, making for righteousness." Evolutionary theology has sometimes been extended by the conjuring up of an anti-evolutionary devil, as in Tennyson's lines:

> Evolution always striving toward some ideal good,
> And Reversion always dragging Evolution in the mud.

All this is, however, mere confusion of thought. Properly speaking evolution does not necessarily make for good, nor is it going anywhere in particular. Selection will alter the human race, but the direction of the change depends on the social environment, and this is fashioned by ourselves. The evolutionary God, like so many others, has been created in man's own image.

This is the crux of the eugenic problem. There is almost no limit to what man might make of himself by altering his genetic constitution; but these possibilities can be realized only if he first becomes more altruistic and intelligent, and he is not sufficiently altruistic or intelligent to take this first step. Hence an attempt to put eugenics into practise would defeat its own ends. Any group likely to be entrusted with a eugenic program would be too unintelligent to recognize merit and too selfish to select any merit they might recognize. They would pick out for propagation individuals of mediocre ability and of less than mediocre morality; that is, those stupid enough to have no independent ideas and those dishonest enough to pretend to have none. Shelley was

deprived of his children by a court of law; a eugenic tribunal would have sterilized him. Barabbas is always preferred to Jesus, at any rate before Jesus is crucified.

Such reverse selection must have been going on throughout man's existence. It was remarked long ago that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favor to men of skill; and since the writer of those words said that there is nothing new under the sun, the survival of undesirable traits must have been an old phenomenon in his day. Even in prehistoric times, as Darwin pointed out, the bravest and most unselfish individuals of a tribe were less likely to survive and to leave offspring. All this would help to account for the fact that there has been, so far as we can tell, no improvement in the innate mental qualities of mankind throughout history, or for that matter since the end of the Cro-Magnon period. This lack of advance must be due also to the fact that man is no longer divided into small isolated groups; for the larger the population, the more difficult it is for a new trait to establish itself, especially if it is a trait like unselfishness.

There are even indications that a decline may have occurred: the Cro-Magnons were in many respects superior to the Neolithic men who succeeded them, and Galton rated the ancient Athenians above the modern English. It is possible that the conditions of civilization put too great a handicap on original and independent thinkers; that the best-adapted type is one with a less inquiring mentality, willing to abide by tradition and to follow routine without question.

The evidence for a genetic decline, particularly in the historic period, is not, however, conclusive. The selection making for a decline has not been rigorous, because of the large element played by chance in human affairs; and it has also been spurious to the extent that it has been based on non-genetic traits. Even where the quali-

ties selected have been genetic, they have not always been perpetuated; for (1) successful individuals are likely to come of infertile strains since in these the families are smaller and the children get a better start in life; (2) even if the successful individual is not infertile he often marries an heiress who, being an only child, comes of an infertile stock and leaves few offspring; (3) successful individuals (the upper classes) limit their families more than the unsuccessful (the lower classes).

Thus there has been a protective mechanism by which the self-seeking and ruthless have been isolated in an upper class and sterilized; while desirable individuals have been kept in the lower classes where they were more likely to reproduce. In this way good genes and combinations of genes have been preserved; but so they would have been if they had been propagated in tissue cultures. Man can not live by genes alone: life is the interaction of genes with the environment.

The extension of opportunity would allow good genotypes to express themselves; but it would not in itself solve the eugenic problem. The mechanism by which the self-seeking have been weeded out would no longer exist; and any attempt at deliberate eugenics would be more dangerous than under the present system since the superior individuals, being more easily recognizable, would be all the more certain to be eliminated. It would be tragic indeed if the human race should fail just when it had become aware of its possibilities, and in the very attempt to realize them.

There is perhaps one way out. Whatever may be true of the huge majority of mankind, there are a few whose instincts are good. If these banded together into a voluntary eugenic comradeship, they could ultimately supplant the others. Provided of course that the others would allow them. We may however be certain that such a project would not be tolerated and that those attempting it would be executed or sterilized. If it were

done at all, it would have to be done secretly; there would have to be a eugenic conspiracy. Probably some day such a conspiracy will be organized; but there is no guaranty that it will be the only one. Other groups are just as likely to form similar conspiracies to insure the perpetuation of their traits; and we can not predict that intellect and good will triumph over intellect and evil—or over stupidity if the odds are too great.

I have been asked who Palamedes was and why this paper is entitled with his name. The question is a good illustration of my theme. Palamedes was the greatest of the Greeks who fought before Troy. He was a scientist and an engineer. He devised a system of writing and methods of arithmetic computation. He traced the movements of the heavenly bodies and used them for marking the hours and for guidance in navigation. He fashioned weights and measures. He built the fortifications of the Greek camp. He even invented checkers and dice to keep the soldiers occupied when they were not fighting. Yet his name is unknown except to classical scholars, while every schoolboy is familiar with Agamemnon, who was only the titular commander-in-chief, and Achilles, who though brave and handsome was a good deal of a brute. And if any one is asked who was the wisest of the Greeks, he will say Nestor or Odysseus. Nestor, however, was wise only in the sense that being very old he could remember many things; and Odysseus was not wise at all but merely unscrupulous. Palamedes and Odysseus once measured wits against each other when Palamedes had been sent to persuade Odysseus to come to the war. Odysseus, unwilling to go, feigned madness and ploughed with an ox and an ass yoked together; but Palamedes placed Odysseus' infant son, Telemachus, before the plough, and Odysseus swerved aside, showing that he was not as mad as that. Odysseus accompanied the Greeks; but when he arrived before Troy he forged letters from the enemy, hid them in Pala-

medes' tent, and accused him of treason. The letters were found, and Palamedes was stoned to death.

It may be said that this is not a fair parable; that Palamedes displayed a want of intelligence in allowing such a plot to succeed. If he could foretell the movements of the stars, why could he not foresee the actions of Odysseus? The objection might be valid if the men had been older, for with experience we learn what our fellows are like; but when we are young each interprets others by himself, since he attributes to others the impulses he himself feels. Odysseus gauged others correctly not because he was wise but because he was evil and it so happened that in this respect most men resembled him. In a better world it is Palamedes who would have been the better judge of men. If we are to make a better world, we must breed people like Palamedes; the danger is that we shall breed people like Odysseus instead.

SOME METHODOLOGICAL ASPECTS OF HUMAN GENETICS[1]

LANCELOT HOGBEN

PROFESSOR OF SOCIAL BIOLOGY IN THE UNIVERSITY OF LONDON

THE most hopeful sign for the future of human genetics is the growing recognition for the need of a special methodology appropriate to the difficulties of studying a species in which mating can not be directly controlled by the investigator. The influence of nature and nurture can not be elucidated by experimental methods such as are employed in the laboratory, and special statistical difficulties arise from the small size of the family. To these three cardinal difficulties, which must be distinguished from merely practical obstacles to rapid progress in the study of human inheritance such as the protracted adolescence of the human species and the large number of human chromosomes, a fourth must be added, when we direct attention to genetic differences involved in differences of social behavior. This is that man is the most teachable of all animals, above all an animal with an unusually complex development of the investigatory reflexes, and the only animal in which an elaborate system of communication through the medium of speech exercises a predominant influence upon social relations. On this account human society is a unique biological phenomenon with unique laws of evolution.

Two types of inquiry into the phenomena of human inheritance may be distinguished. The first is genetic analysis in the traditional sense. By this I mean the recognition of discrete differences in organization (whether structural differences, metabolic differences or differences of behavior) attributable to single genes, and the study of the way in which such genes are related in the mechanism of linkage. The methodological problems involved in connection with manifestations of single gene

[1] Paper read at the symposium on "Heredity and Environment in Man," before the American Society of Naturalists, Atlantic City, December 30, 1932.

substitutions or the interaction of two mutant genes are easily solved on the assumption of random mating when somatic variability is negligible. The magnificent statistical work of Bernstein on the iso-agglutinins and more recent work by Snyder on "taste blindness" shows that the theory of random mating applies with a high degree of precision to the transmission of characteristics which are not readily recognizable. On that assumption the data provided by human pedigrees can be subjected to rigorous quantitative analysis to detect dominant or recessive single gene substitutions of the autosomal and X-borne type. Manifestations involving the interaction of two dominant or recessive genes can also be detected. Subject to one important qualification, which I shall mention later, rigorous genetic analysis on these lines is necessarily confined to gene substitutions which manifest themselves in almost any environment in which the individual can develop. The chief mathematical problems which await solution in this connection are (a) a further consideration of the consequences of assortative mating, (b) further development of the analysis of linkage along such lines as have been indicated in recent communications by Bernstein and by Wiener.

The development of the theory of inbreeding as applied both to autosomal and sex-lined genes offers the possibility of detecting the effect of genes whose manifestation is subject to a significant measure of somatic variability. The consanguinity test is the only one which enables us to distinguish between a single autosomal gene substitution and a double dominant condition when the manifestation of the gene is lethal. A systematic study of the constitution of the progeny of consanguineous unions promises possibilities for the detection of recessive genes which could not be recognized by the application of familial analysis of the kind to which I have referred. Large-scale investigations of this character have still to be undertaken. They might yield information concerning rare recessive genes subject to sufficient somatic variability as to defy familial analysis.

Apart from purely methodological issues, the most urgent practical problem in human genetics is the elucidation of differences which involve genotypes whose frequency in the population is of the same order of magnitude. With a sufficient number of such differences on record, human genetics will be provided with points of reference for assessing the linkage relations of rare genes. Serology offers an extremely fruitful field as the new M–N locus of Landsteiner and Levine emphasizes. The discovery of taste blindness for phenyl-thio-urea compounds shows that serology does not exhaust the field of possible discovery. It is already possible to test whether a rare gene is located upon one of four human chromosomes. We can now hopefully look forward to the time when the twenty-four human chromosomes of man will be mapped.

While the outlook for human genetics in this field of inquiry is vastly more hopeful than it seemed to be ten years ago, it would be a grave error to neglect the difficulties of rapid progress along a second line of inquiry. As distinct from genetic analysis in the traditional Mendelian sense, I refer to the practical problem of distinguishing between genetic differences and differences due to environment in populations where observed differences may be of both kinds. In this field the pitfalls are numerous. One noteworthy feature of a large body of inquiries into the problem of nature and nurture is the prevalence of a somewhat narrow conception of nurture itself. This is well illustrated by a recent inquiry into the genetic status of intelligence tests by Burks. Dr. Burks seeks to establish a measure of the respective contributions of heredity and environment to observed differences in intelligence test scores by correlations with various systems of assessment for home influence. Such methods of inquiry can legitimately be used to answer the question: How far do the class of environmental differences measured by such assessments contribute to differences in test scores? In the nature of the case they

only deal with a very small group of the infinite class of variables which constitute *environment* in the biological sense. By environment in the biological sense we mean all those agencies which contribute to the structure and behavior of an individual in contradistinction to the contribution made by the physical structure of the gametes at the moment of fertilization. In inquiries directed to elucidate environmental influences we are not entitled to make any *a priori* assumptions about the kind of environmental agencies with which we have to deal.

Two points are worthy of special emphasis in this context. The first is the danger of overlooking the importance of uterine environment, and the need for experimental research into factors of foetal nutrition and intrauterine growth. It is only necessary to mention the recent work of Lionel Penrose upon "Mongolian Idiocy" to indicate the importance of the uterine environment, and to draw attention to the significance of order of birth and maternal age as indications of the possibility that differences in uterine environment constitute significant agencies. A second point is analogous. Maternal age and prenatal hygiene are important because there exists between the moment of fertilization and the moment of birth a highly significant period during which differences of physical environment can modify the course of structural development. Between birth and the age at which formal education begins there also exists a protracted and it may be highly significant period during which differences of social environment may affect the behavior of an individual. Hence the comparative constancy of a psychological index such as the Intelligence Quotient offers no presumption in favor of the view that it measures gene differences which would be manifest in almost any environment consistent with existence. While relying too largely on introspective methods and concepts of questionable validity the Freudian school have performed a service to human biology by focussing attention on the importance of the social environment

during the years when the basic patterns of conditioned behavior are established.

The relative importance of nature and nurture (using the latter term in the widest possible sense) raises issues of the greatest practical interest to the psychologist and sociologist in the field of social behavior. Stated as a problem in biology the relevant issue is: What kind of gene differences are associated with differences in the functional activity of the nervous system, and in what range of environment are they recognizable? To answer this question fully requires the closest association between the work of the geneticist and modern research upon the analysis of behavior. At present geneticists and nerve physiologists fraternize but seldom. In the past genetical discussion of questions touching upon their common field of interest has been very largely influenced by the teachings of the instinct psychologists of a bygone generation. For this reason many speculations upon social evolution prompted by the influence of the natural selection theory in its earlier phase must now be reexamined in the light of modern work on the central nervous system, as well as from the genetical standpoint.

The study of behavior in the lower animals reveals the existence of many simple reflex patterns which are consistent with a very wide range of external conditions. What has emerged preeminently from modern work such as that of Pavlov's school is that the relevant environment in which the behavior patterns of the higher animals arise is not a fixed and static, but a dynamic and ever-changing pattern of stimuli; that this ever-changing pattern of stimuli generates new patterns of conditioned reflexes and that the chronological no less than the spatial relations of the stimuli themselves are significant in producing such new patterns. This leaves the way open to the recognition that human society is a phenomenon *sui generis,* a phenomenon which owes its uniquely dynamic character to human inventiveness and the capacity

of the human species to capitalize the fruits of its tool-bearing pursuits for the use of future generations through the medium of speech and its substitutes. Whatever differences of inborn constitution distinguish individuals and groups of individuals living in different places at different periods, the outstanding biological peculiarity of man is the fact that an *infinitude of different behavior patterns is consistent with the same genetic basis.*

The instinct psychology of the selectionist school encouraged the belief that the student of human genetics would be able to detect simple unit characters in the domain of social behavior. What we now know about the physiology of the nervous system does not encourage such a hope. It is all the more necessary to refine our methods for the evaluation of genetic and nurtural differences. For the study of variation in a population the method of correlation can provide a valuable mathematical instrument so long as the function of mathematics is clearly recognized. Statistical methods are always liable to be used without sufficient appreciation of the fact that mathematical technique is only valid in so far as the specific qualitative features of the problem are stated at the outset. The fruitful use of correlation technique depends upon a careful recognition of the framework of environmental differences and the framework of genetic differences within which a body of observations has been collected. The human family is a unit of physical and social environment as well as a unit of individuals with a community of genetic endowment. The use of correlation technique to ascribe additive contributions of nature and nurture to the observed variance within a population implicitly neglects the correlation between the framework of family environment and the framework of genealogical relationships. For reasons which I shall state at length on a later occasion I believe that the attempt to determine the respective contributions of nature and nurture to human variability is meaningless from the

biological standpoint. What we can ask is whether gene differences are associated with observed differences, and whether such gene differences are manifest throughout a wide or a restricted range of environment.

Thus the suggestion that the respective contributions of genetic and environmental factors may be evaluated by taking into account the theoretical deviation of the "somatic" from the "genetic" correlation with respect to dominance neglects the fact that the environment of sibs is more homogeneous than the environment of individuals belonging to different generations. In addition to this, the theoretical considerations advanced in support of this method do not cover cases where the contribution of sex-linked genes is significant. I shall refer to this later.

In discussing how differences of nature and nurture are related to observed differences in a population, we may distinguish between two general classes of problems. One is to detect gene differences which are manifest throughout the range of environment to which members of one and the same fraternity or family group are exposed, and the other is to detect gene differences which are manifest throughout the whole range of environment to which different families are exposed. Each of these may be further subdivided. Within the first group it is necessary to draw a distinction between members of the same family having the same birth rank (as when plural births occur) and (as is more usually the case) members of the same family and of different birth rank. Within the second group it is necessary to distinguish between members of different families belonging to the same occupational, cultural or geographical group and members of the different families belonging to different occupational, cultural or geographical groups. With these issues before us the following considerations suggest themselves.

(1) To detect gene differences which manifest themselves as differences between individuals of the same birth rank brought up together in the same family, a

comparison of the resemblance of identical and non-identical twins can yield valuable information. Such data must be interpreted with caution, because it is unjustifiable to assume that the environment of fraternal twins is as homogeneous as the environment of identical twins. The fact that members of an identical pair are more alike in other respects will tend to make their choice of an environment more similar than the environment chosen by members of a fraternal pair of twins. Using this method Holzinger comes to the conclusion that the mean difference in I. Q. between members of the same fraternity and birth rank is reduced by rather less than a half, when all gene differences within the family are eliminated. Tallman's figures yield the same result. Herrman, working in my laboratory, has examined five hundred pairs of London twins and arrives at the same estimate as Holzinger. In the light of these findings it is permissible to ask whether any significance can be attached to differences so far recorded for different occupational and racial groups.

(2) A comparison of the resemblance between ordinary sibs and fraternal twins may be used to detect whether birth rank differences limit the exhibition of gene differences. In connection with differences of intelligence the results hitherto obtained support the conclusion that fraternal twins are more alike than ordinary brothers and sisters. To use this method to the full advantage it is necessary to compare with fraternal twins both sibs separated by a small and by a large difference in age.

(3) For detecting gene differences which are recognizable throughout the whole range of nurture to which different families at the same social level or at different social levels are exposed, either of two methods may be used. We may standardize the genetic material by correlations of identical twins reared apart. This has not yet been done upon an adequate scale. A second method is to standardize the family environment of individuals who

are genetically dissimilar. In their admirable study upon intelligence test scores, Freeman, Holzinger and Mitchell, of Chicago University, have placed on record the correlation between adopted children and sibs of the families into which they have been adopted. They have also recorded correlations for intelligence quotients of sibs adopted into different homes. A very significant correlation between non-related children brought up in the same home emerged from this inquiry, and a conspicuous diminution of the correlation for ordinary sibs was obtained.

(4) One aspect of the use of correlation technique has been neglected in the past. My attention was originally drawn to it by a comparison of the correlation coefficients of twins of like and unlike sex. I refer to the effect of sex linkage upon the observed correlations between relatives. For the case of filial and fraternal correlations I have already given a preliminary treatment of this problem and have dealt with it more fully for remote relationships in a later communication. In this context it suffices to say that correlations between individuals of unlike sex may differ from the values hitherto predicted by theory either in virtue of differences of environment associated with sex or the contribution of sex-linked genes. A study of cousin correlations of the maternal and paternal type enables a distinction to be drawn.

My own conviction is that Freeman, Holzinger and Mitchell have made a most significant contribution to the methodology of correlation technique as applied to the nature-nurture problem. When used without proper regard for the limitations imposed by the way in which data are collected correlation methods yield conclusions which throw more light upon the social prejudices of the investigator than upon the problem of nature and nurture. When the experimental issues are clearly defined, correlation methods can provide us with the means of obtaining more exact scientific knowledge of gene differences than we possess at present.

LITERATURE CITED

F. Bernstein

1931. "Zur Grundlegung der Chromosomentheorie der Vererbung beim Menschen mit besonderer Berücksichtigung der Blutgruppen," *Zeitschr. f. Indukt. Abstamm.* 5; *Vererbungslehre*, Bd. LVII, 2–3.

Burks

1928. "The Relative Influence of Nature and Nurture upon Mental Development. A Comparative Study of Foster-parent-foster-child Resemblance and True-parent-true-child Resemblance," 27th Year-book N. S. S. E. Part 1, Chap. 10.

Freeman, Holzinger and Mitchell

1928. "The Influence of Environment on the Intelligence School Achievement and Conduct of Foster-children," 27th Yearbook N. S. S. E. Part 1, Chap. 9.

Haldane and Moshinsky

——. "Partial Inbreeding in Mendelian Populations, with Special Reference to Human Cousin Marriage." In press.

Herrman and Hogben

——. "The Intellectual Resemblance of Twins." In press.

Hogben

1931. "The Genetic Analysis of Familial Traits. I. Single Gene Substitutions," *Jour. Genetics*, Vol. xxv, No. 1.

1932. "The Genetic Analysis of Familial Traits. II. Double Gene Substitution," *ibid.*, No. 2.

1932. "The Genetic Analysis of Familial Traits. III. Matings Involving One Parent Exhibiting a Trait Determined by a Single Recessive Gene Substitution with Special Reference to Sex-linked Conditions," *ibid.*, No. 3.

1932. "The Factorial Analysis of Small Families with Parents of Undetermined Genotype," *ibid.*, Vol. xxvi, No. 1.

Hogben, Worrall and Zieve

1932. "The Genetic Basis of Alcaptonuria," *Proc. Roy. Soc. Edinburgh*, Vol. LII, Part III, No. 13.

Hogben

1932. "Filial and Fraternal Correlations in Sex-linked Inheritance," *ibid.*, Vol. LII, Part III, No. 19.

——. "The Correlation of Relatives on the Supposition of Sex-linked Inheritance," *Jour. Genetics.* In press.

——. "A Matrix Notation for Mendelian Populations," *Proc. Roy. Soc. Edinburgh.* In press.

Holzinger

1929. "The Relative Effect of Nature and Nurture Influences on Twin Differences," *Jour. Educ. Psych.*, Vol. XX, No. 4.

Landsteiner and Levine

1931. "The Differentiation of a Type of Human Blood by Means of Normal Animal Serum," *Jour. Immunol.*, Vol. XX.

MUTATION AND ADAPTATION AS COMPONENT PARTS OF A UNIVERSAL PRINCIPLE:

II. The Autocatalysis Curve

PROFESSOR EDGAR J. WITZEMANN

Laboratory of Physiological Chemistry, University of Wisconsin

In the previous section of this essay[1] we have traced out the rather surprising similarity of behavior of vapors and liquids, chemically reactive gaseous mixtures, plant species and certain other systems, on both sides of a critical zone, which was thought to be analogous to the state of mutation, or mutability, in plants as observed by DeVries. On both sides of this critical zone the systems appear to behave according to the Law of Adaptation. Our final picture then indicated that we have brief periods of mutation connected by long periods of adaptation, which DeVries had stated constituted a correct account of the history of plant species.

Such a series of discontinuities can only develop the quality of continuity if viewed as periodic systems. Periodicity is universally found and probably arises directly and indirectly from the manner in which the common forms of energy are propagated, principally from the sun. The form of the periodic cycles thus obtained appears to differ in one important respect. Whereas the periodic cycles involved in evolution are believed to manifest a progressively upward trend (or downward in case the change is regarded as degeneration) the pulsations representing heat, light and electricity are represented as moving parallel to one of the rectangular coordinates. However it is obvious that these rhythmical processes are represented in this way simply for convenience. By the introduction of a suitable constant any desired angular relation to the coordinates could be ob-

[1] Amer. Nat., Vol. LXVII, No. 709, p. 163.

tained. A similar result could be achieved by changing the coordinates. Thus for instance the swinging of a perfect pendulum may be represented so that the record of its oscillations would lock something like the curve given in Fig. 1 in which C is the distance traveled and T is the time elapsed.

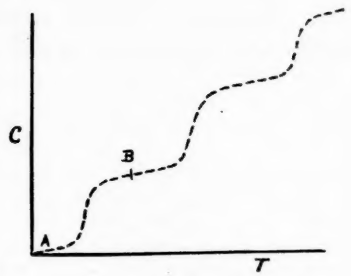


FIG. 1

If we take into account the fact that the two halves of a complete cycle have opposite signs, then one half of a complete oscillation would be represented by the line AB. The course of the whole process is recorded by passage from A to B and back again. Such a representation does not give us the history of the process that we are watching. For some purposes this would be of no consequence, but under other circumstances, as for instance when we wish to record time, the oscillations lose their identity and therefore their value as a means of measuring time unless some way of recording or designating the recurring rhythms or cycles is used.

It is important to note that many of the rhythmical cycles that have been previously mentioned are of this monotonously similar sort. Unless carefully observed each cycle is just like the other. Thus each day and night is for practical purposes alike, but it happens that for all of us certain days achieve a particular importance and so we find it necessary or desirable to mark each day, in order to give it its proper place in relation to the days

of other people. History, for the Greeks, lacked this chronological characteristic to a large extent.

But it is not the chronological aspect of our curve that we wish to consider. To any one familiar with the phenomena of autocatalysis it is at once evident that the portion *AB* of the curve in Fig. 1 represents the course of an autocatalyzed chemical reaction. In such reactions something occurs within the system that makes the reaction take place more and more easily. The typical form

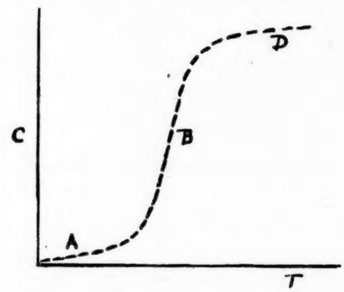


FIG. 2

of the curve is given in Fig. 2 and consists of a preliminary part *A,* known as the induction period, in which the change in *C* takes place very slowly. This is followed by a period of rapid change *B,* and then by a final period *D,* in which the change is slowly completed. It is evident that we are here dealing with phenomena that in some fundamental respect resemble those that we were discussing above. The fact that the phenomena in question are so different makes it difficult to see any relation, but the similarity of the curves is unmistakable. *A* represents an adaptive foreperiod, which in autocatalysis provides for the growth of the autocatalyst, *B* represents the period of mutation, or maximal activity of the autocatalyst, *i.e.,* a period of rapid change, and *D* is the period of completion and the foreperiod of the next cycle. In the physical processes that are represented by this curve we measure the ebb and flow of kinetic or potential energy

depending on our point of view; in the autocatalyzed processes we measure the rate of transformation of matter.

That such autocatalysis is probably a special case of a universal phenomenon has been recognized for some time and Wo. Ostwald invented the suggestive term autocatakinesis for the general phenomenon. T. B. Robertson has written a very interesting discussion of this topic under the heading "Growth as an Autocatalysis"[2] from which the following is taken:[2]

> This process (growth) does not take place with uniform velocity throughout life. . . . the process of growth is not one which undergoes uniform retardation, diminishing in velocity by a similar proportion per annum. On the contrary the growth of children, as also that of animals or plants, takes place in spurts, separated more or less distinctly from one another by periods of relatively languid growth. Thus, the rate of growth *in utero* during the first half of gestation is so slow that the weight of the human fetus is inappreciable in comparison with that of the mother during this period. This interval of slow growth is succeeded by the extraordinary rapid accretion of tissue which characterizes development during the months immediately prior to and succeeding delivery.
>
> Towards the end of the first year of extrauterine life, however, there occurs a definite slackening of growth which is not an artifact. . . . This resting period or "plateau" in the curve of growth is succeeded by the relatively rapid growth of the third, fourth and fifth years of life. Another pause or slackening of growth succeeds this, to be followed by the energetic growth which accompanies adolescence. (*Loc. cit.*, p. 1–2.)
>
> Similar growth curves have been obtained for every animal that has been studied. In seeking to interpret the meaning of this characteristic of the growth-process, we are immediately led to inquire whether any chemical processes of this particular type are known to occur elsewhere in the tissues of a growing organism.
>
> As a matter of fact a number of processes of this character are familiar to the chemist. As examples we may cite the decomposition of cane sugar by boiling (neutral) water (Kullgren, *Zt. physik Chem.* **41**, 407 (1902)), the decomposition of castor oil in the pulverized seeds of the castor bean (Constein, *Ergeb. d. Physiol.* 3, 194 (1904), the decomposition of methyl acetate by initially neutral water (W. Ostwald, *J. prakt. Chem.* (2), **28**, 449 (1883)), the oxidation or "tarnishing" of metals and the oxidation of a variety of organic materials (J. W. Mellor, *Chemical Statics and Dynamics*). All these diverse processes have this feature in common, namely, that one of the products of the chemical change which is going on has the property of accelerating or "catalysing" the further progress of the change. . . . all of these processes are in a word "autocatalysed" or self-acceler-

[2] "The Chemical Basis of Growth and Senescence," 1923.

ated. The fact that the reaction has occurred is, up to a certain point, a favoring condition for its further occurrence. (*Loc. cit.*, p. 5–6.)

The fact that each growth cycle begins slowly and progressively increases in velocity until the moment of maximal growth-velocity is attained, at the center of the cycle, is sufficient in itself to show that the process of growth is autocatalysed. Up to the moment of maximal growth-velocity, the preceding growth affords a condition or series of conditions, favoring its continuance. The analogy extends much farther than this, however, for it has been found in a number of instances that in a cycle of growth the relationship of mass (or weight) to time is quantitatively identical with that which is displayed in autocatalytic reactions which have just been cited (*cf.* Chaps. II and III of this book for data). (*Loc. cit.*, p 6.)

The phenomenon of growth has also been dealt with by Lotka. In an interesting chapter[3] he has discussed the Law of Population Growth (the curve for which is similar in form to that for the Law of Autocatalysis which we are discussing) in terms of a general equation having a single variable. He showed that it has been applied quite accurately to the growth of the population of the United States (1790–1910) and to experimental populations such as Drosophila (fruit-flies) and to the growth of individual bacterial colonies. In connection with the behavior of the bacterial colony Lotka[4] writes as follows:

A very particular interest attaches to this example, inasmuch as it forms, as it were, a connecting link between the law of growth of a population, and the law of growth of the individual. A colony of unicellular organisms, regarded as a whole, is analogous to the body of a multicellular organism. Or, to put the matter another way, a man, for example, may be regarded as a population of cells. We need not, therefore, be greatly surprised, if the growth of the multicellular organism should be found to follow a law similar to that exhibited by populations.

It is only fair to Lotka to state that he considers the analogy between the law of growth and the law of autocatalysis interesting, but he says it

must not be taken too seriously, inasmuch as in the one case the rate of growth is determined by ordinary chemical influence, in the other (organic growth) by a complicated combination of factors both of chemical and of physical character. Rather more to the point seems to be the suggestion made above in connection with the law of growth of bacterial colonies, that

[3] Lotka, "Elements of Physical Biology," Chap. VII.

[4] *Loc. cit.*, p. 69.

the body of the multicellular organism being a population of cells, it is not altogether surprising that it should be found to follow the law of growth of population.

The writer is under the impression that by a similar extension a chemical system is a "population" of molecules the growth of which is determined "by a complicated combination of factors both of chemical and of physical character." That is to say, the distinction pointed out by Lotka does not really exist. The important difference is the difference in "scale."

The above is sufficient to show that there is a fundamental similarity in these growth processes and those of an autocatalyzed chemical reaction. In some instances the process is complicated by the subsequent appearance of another cycle as in the growth studies of Robertson. If we assume that the retardation at the end of the first cycle is due to a depletion of one of the components, and if we attempt to determine which component it is, we must conclude that it is the autocatalyst that is depleted, because the cell group continues to live and the food supply is undiminished. Since there are three growth cycles in these animals we may assume that the same autocatalyst is developed three times in the life of the organism, or that each growth period is catalyzed by a different autocatalyst or autocatalytic system, and that as in physico-chemical systems we must know the history of our organism, as well as its life history, before we can predict its future behavior. A rat, for example, is bound by the same law as that which controls a gas, when considered in this way. Physiologists are already seeking for such a series of autocatalysts and a number of them have been found, but the details of these processes are still far from clear. Some of the factors involved are revealed by statistical studies concerning the growth of organs. The development of a maximum relative size for a given organ in a period of maximum in the growth and development of the organism as a whole, suggests a

regulative rôle for the organ in question. Since so far as is known the same organ never enters a maximum of this sort twice in the life of a normal individual it seems certain that different autocatalysts control the different maxima. If two or more autocatalysts are involved in giving rise to any given stage or change they may be regarded as constituting an autocatalytic system. In such a way we can view the process as controlled by a single variable, and we can for the moment leave out of consideration the fact that the variable itself often has a somewhat complicated history. In fact its formation may in turn be autocatalyzed at lower stages, and it may as a matter of fact show other effects in some of its stages or phases that render its chemical visualization and interpretation difficult, but this does not modify the fundamental simplicity of its action when considered *in toto*.

The idea of such autocatalyzed autocatalysts or cycles within cycles will become clearer in subsequent parts of this paper.

The life cycle: In the preceding section we have discussed the growth of a higher organism (typically mammals) as a succession of three autocatalysis cycles. In this section we wish to show how this cycle, or series of cycles, is followed by a reproductive cycle and then by extension we see other cycles. Finally, it becomes clear that a given organism may at a given moment be considered to be in several stages of rhythmic cycles having different "wave-lengths." The position of the organism in question upon an autocatalysis curve will then be determined by which autocatalytic process is being considered. It appears that the living organism in its parts and as a whole is involved in a large series of rhythmic cycles that are just as different in their "wave-lengths" as those emitted by the sun. We have the intra-atomic cycles and the molecular cycles in common with all matter. Then we have the physico-chemical intermolecular cycles involved in dialysis, adsorption, etc., by which the rhythmic quality of chemical interaction in the cell is pro-

duced. Then by small stages we come to the more obvious physiological rhythms, such as the flashing of a firefly and others, like peristalsis mentioned above. Then perhaps we come to the rhythmic rest periods produced by the alternation of day and night and winter and summer. Above these and with still longer "wave-lengths" come other rhythms in the life of the individual and the race that we now wish to discuss briefly.

These longer rhythms can best be discussed on the basis of examples. A carrot seedling, to take a simple example from the plant kingdom, is endowed with a sufficient store of food to elaborate and raise its "energy-binding" apparatus above ground. Here the light of the sun falls upon the chloroplasts of the carrot plant and solar energy is captured and stored, in part, in daughter chloroplasts called leucoplasts, principally as carbohydrates in the root. At first a considerable portion of the stored energy is used to extend the energy-binding machinery to make more chloroplasts. The storage of solar energy as starch by the leucoplasts is continued until the seasonal growth of the carrot is complete. The year's work is now done. The plant rests. When the carrot renews its growth the following season, it being normally a biennial plant, it appears to be possessed with a different "motive." Whereas in its first stage of growth it was an energy trap, a builder of a "savings account" in the form of a large tuberous root, it now seems to have "forgotten" all about this. Its chief interest now becomes that of an "unselfish self-sacrificing parent." The fine mature carrot spends itself in the reproductive effort of producing and of maturing its seed and then perishes. The seeds produced again repeat the cycle of the parent possessed of the same motive or "drive" at the corresponding stage of development. Each of these two stages of life in the carrot is controlled by its own autocatalyst. In the case of plants the nature of these autocatalysts is very little known, but it is obvious that they play the

same regulatory rôles as the hormones in animals. All plants do not utilize this rhythmic principle in the same way. The discussion of this simple example of the carrot is enough, however, to illustrate the application of the principle at this stage of organization of life.

A baby, like a carrot, is an "energy trap." Unlike the carrot it can not utilize the sun's rays as a source of growth and power, but must use solar energy that has been bound by plants. The destiny of the baby is determined to a considerable degree by the kind of bound energy offered to it and by the kind of a "trap" that it is. A proper ability to digest and convert food into more baby is a fundamental prerequisite. Presently under favorable conditions the baby, like the carrot, completes its growth and enters into the second cycle, or reproductive cycle of its physical existence. In the case of higher animals we know that this is coincident with the maturation of the sex organs and that the physiological aspects of its activities in this respect are controlled by internal secretions, that are carried back into the blood from these organs and that affect every physiological reaction and every psychological reaction of the organism in question, to a greater or less extent. In this case the autocatalytic curve is fully developed in recognizable form. We have the period of adaptation or growth of the autocatalysts in puberty; we have the period of maximal activity or mutation and then the period of completion at the end. But when we come to look at this long cycle more closely we see that it is accompanied by shorter seasonal cycles and physiological cycles so that in this field we can again find autocatalytic cycles of almost any "wave-length" that we desire, up to that of the maximum length of the reproductive cycle itself.

We thus see that the growth cycle and the reproductive cycle have the form of autocatalyzed processes and if nothing further were known about it, we could venture the suggestion that they are controlled and determined

by two series of physiological autocatalysts. As it happens some of these are already known to be internal secretions of certain tissues. It is worthy of note that the maxima for these autocatalytic processes come at different periods in the life-history of the individual. Thus man normally attains his growth and passes through his physical maximum of strength and power at or before his twenty-fifth year. By this time the growth autocatalysts have receded in importance, but the reproductive autocatalysts are just rising to their maximum. Meanwhile he has not yet attained intellectual maturity. The autocatalysts of intellectual power are somehow dependent upon those pertaining to growth and sexual ripeness, but the appearance of the maximum is delayed. In fact the best fruit of the mind is normally scarcely set before the fruit of the body has largely ripened and dropped off the tree, so to speak.

Finally, there is normally another growth that is also apparently secondarily dependent upon the completion of the functions of the autocatalysts of growth, of reproduction and of intellectual power. This we may call the growth of the spirit or the soul of man. The development of this indefinable quality is slow and appears to be dependent upon the successful completion of a normal maturity in the other processes enumerated. In this the development of the autocatalyst requires a longer period and the maximum usually appears late in the life of the individual. This is perhaps the most complex integration or coordination of the details of function and experience that is achieved in the life of man and up to the present our appraisal of the result of this development in any individual is largely intuitive. In fact it is almost impossible to discuss the matter in satisfactory terms.

Each of these autocatalytic waves is longer in duration than the preceding. The relations may be visualized from the diagram. It seems likely that the development

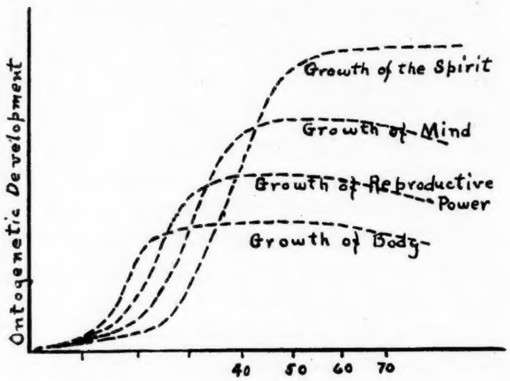


FIG. 3

of the autocatalysts for all of them takes place simultaneously, but in any case they come to maximum fruition at different times. At some stage each represents a prevailing preoccupation of the human race as a whole, and life is dominated by a different interest at each stage of the life of the individual. It is a well-known fact that failure to develop the autocatalysts of growth is physically fatal in the earlier stages of life. A baby that does not grow does not live long. Similarly failure to grow at later stages is also fatal to the proper growth and maturation of mind and soul. The problem of education and nurture is that of supplying the proper "building stones" or raw material to a system capable of utilizing them. These two agents then cooperate to build these intangible and almost inconceivable "catalysts" of the mind and soul. Here we have a profound chemistry about which we can say little or nothing at present.

Résumé: In the first section of this essay we reviewed a wide variety of phenomena in which two adaptable states are connected by a state of change or mutation. A graphical representation of these phenomena gives us an "S" curve that resembles the autocatalysis curve of

chemistry. The question at once arose as to whether this principle of rhythm or periodicity that is obtained by a synthesis of "adaptation" and "mutation" has any real relation to autocatalysis. For a restricted chemical or physical process as carried out in the laboratory the phenomena discussed in the first section and those of autocatalysis are subject to the same limitations. Usually not more than one cycle is observed. However, in the freer states of nature, particularly under the organizing influence of life processes, we found a succession of autocatalyzed processes. We found the form of the curve to be an indication of the existence of processes of this sort. Before attempting to get some general picture of what is taking place in these diverse systems, that makes them resemble each other, we ought to proceed somewhat farther in the next section with the description of this astonishing system of rhythmical and periodical phenomena.

SHORTER ARTICLES AND DISCUSSION

DICE ON GEOGRAPHIC VARIATION IN PEROMYSCUS

MAMMALOGISTS used to content themselves with studying, describing and classifying the skins and skulls of animals caught in the field. On such studies species and subspecies were defined and their geographic ranges mapped. But the up-to-date mammalogist is skeptical of the true significance of museum specimens. Before he accepts a particular specimen as typical of its species he wants to know how old it was when killed, at what time of year it was killed, and in what kind of an environment it had lived previously. Such data are seldom obtainable for field-caught specimens. So present-day mammalogists are taking to raising their own specimens under controlled environmental conditions and killing them for study when full growth and a known age have been attained.

A model study based on such material has recently been published by Dr. L. R. Dice.[1] It is of importance to students of evolution in general and of mammalian genetics in particular. That its significance may not be overlooked I venture to comment upon it.

The most widely distributed and commonest of North American mammals is probably the deer-mouse, Peromyscus. The well-known monograph of the genus by Osgood made some years ago has served as a basis for the subsequent intensive combined field and laboratory study made by Sumner and now being continued by Dice.

The particular study on which Dice now reports was made on the geographic variation of a single subspecies of Peromyscus which occurs throughout the corn-belt, ranging from Michigan and Ohio west and south across Indiana, Illinois and Missouri to Oklahoma and thence north to Manitoba. Dice collected animals from three widely separated localities within the range of this prairie subspecies, (1) Ann Arbor, Michigan, near the eastern limit of its range, (2) Alexander, Iowa, in the north-central portion of the range, and (3) Grafton, North Dakota, near its extreme northwestern limit. Young to the number of a hundred or more were reared from animals caught in each of these widely separated localities. All were kept under similar laboratory conditions and killed at similar ages. Weight, body

[1] L. R. Dice, Occasional Papers, Mus. Zool., Univ. of Mich., No. 239, 1932.

dimensions, skeletal dimensions, and pelage were carefully compared and recorded.

As regards the pelage "only relatively slight geographical differences in color" were observed, but as regards "the dimensions of several parts of the body and skeleton" significant differences are recorded.

Thus the North Dakota mice average about five grams heavier than the Ann Arbor mice; their body length is about four mm greater, their hind-foot about 1 mm longer and their ear-length more than 1 mm greater. Also femur length and skull length are greater in the North Dakota mice by about 1 mm. In short they are bigger animals in all dimensions.

These differences occur in animals bred in captivity under the same laboratory conditions and can accordingly only be referred to racial or genetic causes.

The Iowa mice, intermediate in geographic position are also intermediate in weight and body dimensions.

A glance at Dice's map of the range of the subspecies studied shows that the Mississippi river cuts squarely across the middle of it. Hence there can have been little interbreeding across this barrier since glacial times.

The only difference which can now be clearly discerned between animals occurring at opposite extremes of the range (after many centuries of separation) is one of general body size.

A prevalent view concerning the nature of size inheritance would regard it as due to the action of many independent genes having local effects. If so, we should expect that while some genes mutated in a plus direction, others would mutate in a minus direction. If so, some body dimensions should grow less while others grew larger. But this is not what Dice observes in the case of North Dakota as compared with Michigan stocks of Peromyscus. All bodily and skeletal dimensions are increased in unison. Dice does not emphasize this point, but I would call particular attention to it because it supports the conclusions reached in the studies which I have made of size inheritance in rabbits. There it is obvious that breed differences in weight, skull length, ear-length and other measurements increase or decrease in unison. This can be referred not to a multitude of independent genetic agencies, as the multiple factor hypothesis of size inheritance would seem to require, but to a single common agency. This common agency has been shown by studies of Gregory and myself to be in all probability developmental

rate of the embryo. What the genetic basis of *that* is remains yet to be demonstrated. It seems nevertheless to be an advance to be able to substitute a single unknown variable for many independent ones.

I would suggest that the only obvious evolutionary change which is occurring in *Peromyscus maniculatus bairdii,* as indicated by the intensive studies of Dice, is the development of slight differences in general body size at opposite extremes of its range. This difference is manifested in weight and various bodily and skeletal measurements, perhaps referable alike to a single agency, as in the case of the much greater size differences among domestic rabbits which all result naturally and of necessity from a difference in developmental rate of the embryo.

W. E. Castle

Bussey Institution,
Harvard University

"LEADEN," A RECENT COLOR MUTATION IN THE HOUSE MOUSE

With the increasingly large number of mammals now being raised for experimental purposes and kept under close laboratory observation, there is furnished a much greater opportunity for the detection of any visible change in the established characteristics of the stock animals. Such large groups of mammals tend to produce occasional variations not normal for the stock, but the detection and preservation of point mutations is still relatively rare.

Mutant characters in the house mouse, *Mus musculus,* are now being genetically established more often than in the past, due to the expansion of interest in the use of this valuable laboratory mammal, so that the species now has at least one known character on ten different chromosomes. The absence of known characters on the remaining ten chromosomes makes it imperative to test all new mutants as soon as they are genetically established in order to ascertain whether the character in question is independent and on a new chromosome or linked with one of the known chromosomal groups.

It is the purpose of this paper to report the origin of a new recessive mutant from a closely inbred strain of animals, to show the linkage tests and give a comparison of the first six generations of the mutant strain and the strain from which it arose.

A strain of mice known as "chocolate brown" has been inbred as a control stock in these laboratories for several years. Geneti-

cally the animals are non-agouti brown (aabb). In 1925, when the strain came under the writer's care, they were eleven generations inbred, having been produced from one pair of black animals which carried the recessive brown. The usual method of breeding has been to make brother to sister matings. When this was impossible a back-cross to the parent was made.

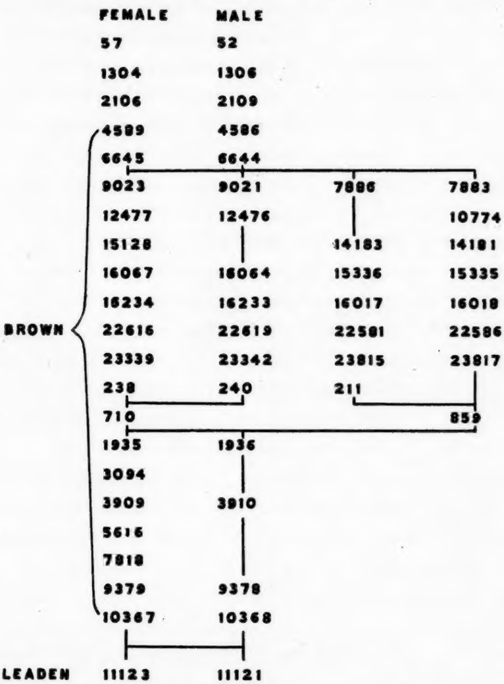


FIG. 1

Fig. 1 is the pedigree chart which shows each recorded mating preceding the origin of the mutant character.

From this pedigree it will be seen that in the fifth generation two lines were established from two litters by the same pair of animals. In order to keep the strain viable these lines were united again to produce the fourteenth generation.

A great deal of difficulty was experienced in one particular line derived from this fourteenth generation. It was found necessary to back-cross to get the sixteenth generation and the male from this sixteenth generation was used to produce the 17th, 18th and 19th generations.

In the 21st generation a male and female were produced in the first litter from a mating between ♀ 10367 and ♂ 10368 which exhibited a marked dilution in the coat pigmentation. This dilution has proven to be independent of any known dilution factor and we have designated the character from gross appearance as "leaden," and given it the symbol "l."

Because of the phenotypical similarity between the leaden and blue dilution, as it appears in combination with brown, the progenitors (♀ 10367 and ♂ 10368) of the leaden animals were outcrossed to highly inbred blue-dilute (bbdd) animals. Male 10368 produced nine litters with 39 viable young, and female 10367 produced two litters with 9 viable young. All these offspring were chocolate brown in color. Although blue-dilution has never occurred in thousands of animals in the brown stock, these tests were made to eliminate the possibility of contamination in the particular animals giving rise to the leaden mutants.

Back-cross matings between leaden females and male 10368 produced seven brown and twelve leaden young. In back-cross matings between leaden males and brown females, heterozygous for leaden, six litters produced twenty-six brown and fourteen leaden young. These tests show the intense brown to be completely dominant to the leaden dilution.

Linkage tests were then begun by mating highly inbred dilute brown females to leaden males. Twenty-four litters of this cross produced 114 viable young, all of which were chocolate brown in color. This F_1 generation served as a final test to show that the new mutant color was not governed by the same gene as blue-dilution.

For linkage tests between dilute and leaden, the back-cross between F_1 animals and the double recessive was desirable, but it became evident, after several litters of F_2 animals had been weaned, that this test would be involved by the fact that double recessive animals were not phenotypically distinguishable from the homozygous leaden individuals which were heterozygous for blue-dilution or did not carry blue-dilution at all.

Of the animals tested, two males from the leaden and dilute leaden class in the F_2 generation were found to be homozygous for both blue-dilution and leaden. In the eighteen litters produced by mating these double recessive males to F_1 females, 154 young were raised and classified as follows:

Class	DL	dL	Dl + dl
Ratio exp.	1	1	2
Data	43	37	74
Expectation	38.5 ± 3.6	38.5 ± 3.6	77 ± 4.18

In order to substantiate these data a large F_2 generation was raised. According to expectation this F_2 generation should segregate in a ratio of 9 : 3 : 3 : 1 between chocolate, dilute, leaden and dilute-leaden. In this cross 853 animals were weaned from the 898 young born (102 litters) and were classified for coat color. Distribution of these classes is as follows:

Class	DL	dL	Dl + dl
Ratio exp.	9	3	4
Data	510	148	195
Expectation	479.7 ± 9.77	159.9 ± 7.68	213.2 ± 8.52

The excess of brown animals, a little over three times the probable error, is no doubt due to the fact that a postnatal selection was introduced in favor of the intense brown class. The litters produced by this cross were very large and since the young in the brown class were easily detected at six or seven days of age they were killed off to allow the dilute colored sibs a better chance for survival to weaning age. The data may be more accurately presented if only complete litters are used, that is, litters in which there was no mortality between birth and the time of classification for color, and in which no postnatal differential viability of young need be considered.

Sixty-eight of these undepleted litters produced 595 young with essentially the same distribution as was found for the total number of animals as classified in the last table.

Class	DL	dL	Dl + dl
Ratio exp.	9	3	4
Data	353	103	139
Expectation	333.9 ± 8.15	111.3 ± 6.41	148.4 ± 7.11

From the data of these tests there are no indications of linkage between the characters blue-dilution and leaden. In order to further substantiate these data similar tests were made with

short-ear, a character which has been reported to be very closely linked with dilution. Here also negative results were obtained.

The results of linkage tests with albinism, black, agouti, hairless, naked, dwarf, waltzing, dominant spotting and short-ear are tabulated in the following table:

Back-cross	XL	Xl	xL	xl
Black BbLl × bbll	69/70.5 ± 4.9	70	72	71
Agouti AaLl × aall	35/32.0 ± 3.3	38	26	29
Hairless Hrhr × hrhrll	24/22.5 ± 2.79	26	26	15
Naked NnLl × nnll	47/40.5 ± 3.72	37	39	39
Dominant-spotting WwLL × wwll	55/55.0 ± 4.33	51	56	58
Short-ear Sese × sesemm	45/51.2 ± 4.18	52	47	61
F_2				
Albinism CcLl × CcLl	182/189.9 ± 6.16	61/63.3 ± 4.85	96 84.4/ ± 5.37	
Hairless HrHrLl HrhrLl	59/58.5 ± 3.4	16/19.5 ± 2.67	19/19.5 ± 2.67	10/6.5 ± 1.66
Dwarf DwdwLl × DwdwLl	52/46.7 ± 3.0	16/15.6 ± 2.40	8/15.6 ± 2.40	7/5.2 ± 1.49
Waltzing VvLl × VvLl	72/79.8 ± 3.99	27/26.6 ± 3.14	34/26.6 ± 3.14	9/8.87 ± 1.95

In the tests with these nine characters the data show no indication of linkage, the segregation in each case being close to expectation for free assortment.

As is shown by the pedigree chart of the brown stock, before the mutation occurred the line of animals appeared to be getting progressively weaker. Only by an unusual amount of back-crossing was the line kept viable. It is of interest to note that following the germinal changes which manifest themselves in a recessive color character, the fertility and viability of the ani-

mals in the line was improved. This is shown in the breeding records of the two stocks when a comparison between the mutant and the last six generations of the brown stock is made.

Tabulated below are the data on age at first litter, number of young at first litter, percentage of young born dead, and percentage of young viable at weaning age (one month).

	No. litters	Ave. age 1st litter	Ave. no. young	Per cent. young born dead	Per cent. young weaned
Brown stock	680	103.4	5.83	9.12	42.4
Mutant stock	259	97.8	6.1	4.38	58.6

Since all the animals in both stocks have been kept under as uniform conditions as possible it would seem that these data are significant and show an improvement in the general physiological constitution of the mutant stock. This improvement over the original stock is not marked, but is uniformly better in all respects. Such improvement is not generally found when recessive mutant forms arise.

The material provided by this mutant is unique in that the records of inbreeding and long period of observation on the stock from which it arose are available for comparison. Arising from a stock which in general is above average in fertility and viability, the germinal readjustment has apparently eliminated weakening modifiers in the particular line from which it arose and has established a better physiological level than is found in the original stock as a whole.

J. M. Murray

Roscoe B. Jackson Memorial Laboratory
Bar Harbor, Maine

PROTOZOANS AND BEETLES

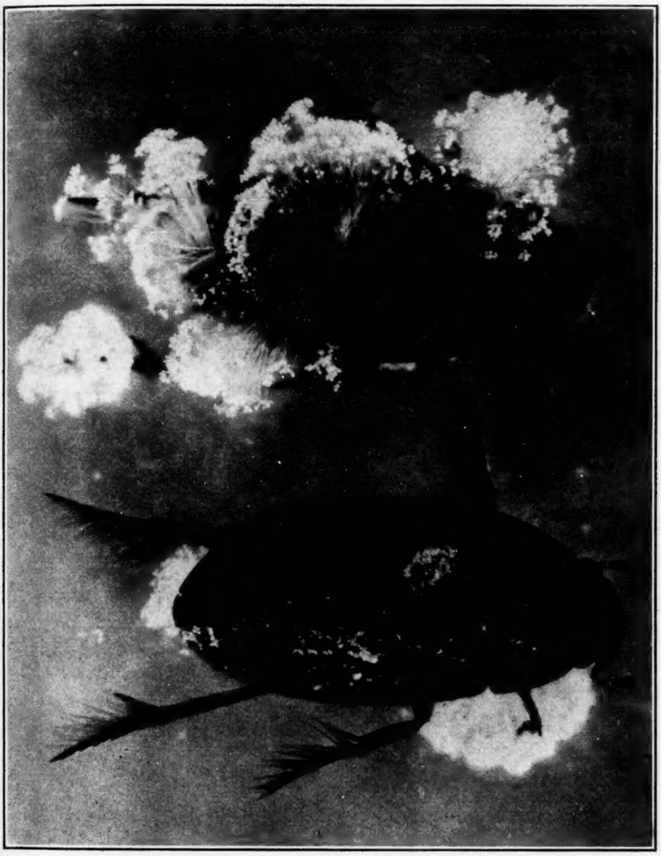
The intimate relationship between certain insects and protozoans are well known to students of entomology and parasitology. The degree of the association may vary from true parasitism to harmless commensals with many intermediate stages. As examples of true protozoan parasites on insects *Nosema apis* and *Nosema bombycis* claim validity; the former causing a serious disease of honeybees, and the latter threatening the silk industry of France by causing pebrine in the silkworm larvae before the arrival of Pasteur. Less pronounced effects of parasitism in insects by protozoans are found among Gregarina, which parasitize beetles, cockroaches and grasshoppers.

Intermediate forms of associations, we find beautifully represented in certain protozoans and termites where the symbiotic relationship apparently has reached the acme of perfection. We are less certain as to the nature of the symbiotic relationship found in the malarial parasite and the mosquito. Whether the presence of sporozoan parasite in the digestive tract of the mosquito, with the consequent penetration of the stomach wall by the ookinete and cyst formation, causes any inconvenience or injury to the mosquito remains an unsolved problem. Histological studies indicate disturbances in the tissues but nothing is known as to the ultimate effect on the duration of life of the mosquito. There is an urgent need for careful studies on this subject.

Protozoan organisms involved in parasitism and symbiosis seem generally to require access to the internal tissues, including fluid tissues, while organisms in commensal relationship to insects appear less discriminating and exacting, and are frequently satisfied with merely clinging to the outside of the host. The chitinous, sometimes punctated, or roughened surface of the insect exoskeleton lends itself admirably for attachment of certain sessile forms of protozoa.

The writer's attention was called to an interesting case of commensal relationship between certain protozoans and aquatic insects while collecting beetles in a fresh-water pond in Oakland, California. White masses, identified as colonies of protozoans of the genus Epistylis, were found clinging to the various parts of the body of the hydrophylid beetle, *Tropisternus californicus.* One hundred twenty-four specimens were collected, and one hundred twenty-one of this number served as vehicles for the protozoan guest. The extent of the infestation, as well as the lack of preference for a certain location on the body of the beetle, is indicated by the accompanying micro-photograph. The illustration represents an average infestation during the peak of the season, which, in this case, was about the middle of February. The periodic occurrence of the organism is evidently correlated with the cycle of protozoan life, particularly with reference to that of the genus Epistylis. Specimens collected thirty days later, March 15, were almost entirely free from presence of the protozoan "hitch-hiker."

The firm attachment as well as the tenacity and elasticity of the protozoan stalk is remarkable. It was only with considerable difficulty that the organisms could be removed from the beetle and placed on the slide for microscopic examination.



The degree of commensalism in the above relationship presents an interesting subject for speculation. Generally, students of ecology consider commensalism as a more or less harmless or beneficial association between two organisms. The effects of the presence of this protozoan on the beetle is difficult to determine. It would appear that it acts as a distinct handicap to the beetle as the latter seemed to experience difficulty in raising the elytra for obtaining air as it came to the surface to replenish its oxygen supply. The proportionately large clusters of protozoans on the surface of the body would offer resistance to motion through the water and lessen the efficiency of the beetle as a diver. The clusters on the legs, particularly on the hind-legs, would render

the swimming stroke more difficult and less effective. The presence of the organism, however, seemed to have no diminishing effect on the total number or the length of life of the beetle, and they seemed to thrive equally well in the aquarium as well as in their natural habitat. The protozoan, on the other hand, derives some benefit, apparently, from the association by securing free transportation to environments favorable for food and respiration. On the whole, it would seem that the beetle is the loser in the association, as it is hard to think of any benefits accruing to it. A more thorough knowledge of the conditions of this relationship is necessary before it can be assigned to its proper category in ecological thought, and emphasizes the difficulty of corralling living organisms into empirical ecological enclosures.

UNIVERSITY OF CALIFORNIA J. A. ELSON

THE EXCESSIVE ABUNDANCE OF CERTAIN BEES

THE Rev. G. Birkmann resided for many years at Fedor, Lee Co., Texas, and diligently collected and studied the wild bees of this locality, finding many new to science. He has now retired from the ministry, and is living at Hufsmith, Harris Co., Texas, whence he writes me concerning the excessive abundance of a species of bee, *Protoxaea texana* (Friese). The case is of general biological interest, because this species, a large and beautiful insect, has only been found in Texas, and few specimens exist in collections. Thus the ability to multiply enormously, at least under certain conditions, has not caused it to be generally abundant or wide-spread. Mr. Birkmann's account, from which the following is abstracted, is partly from his letters and partly from an article contributed by him to a local paper, the *Giddings News*, of September 2, 1932.

During the last days of August Mr. Birkmann's son reported the abundance of bees in the air, making "a great ado and hubbub flying in all directions, and not only over a small area, but for quite a distance the noise is heard and the ground is full of newly dug holes." Mr. Birkmann went to the place, and confirmed the account. The bees were flying, "some of them only a half foot from the ground, others higher, so as to get over the weeds, still others pretty high up, all of them flying fast and like so many little furies, making all the noise possible to them. You could hear them at some distance, the sound was similar to that heard in the telegraph wires at times." The bees flew with such

energy and speed that they would not try to avoid any one standing in the way, but struck Mr. Birkmann's body and hat. Some of the nest holes went down several feet, but it was not always easy to measure them with a switch as they were often curved or irregular. The diameter of the holes was about half an inch. The soil dug out of the holes was of a brick red color, but the surface of the ground was sandy and deep greyish, with very little vegetation, except some plants of *Croton,* which were visited by the bees.

In all his experience, Mr. Birkmann had never known anything like it. He stepped off the ground, and found the area to be about 700 feet in length and 230 in width, with 39 holes in 100 square feet, and 46 holes in another like area. Thus "there were about 80,000 holes, and counting one pair of bees for each hole, there would have been one hundred thousand individual bees. All of the same kind." This lasted for about four or five days, according to Mr. Birkmann's observation; after that "they are in their burrows, and the females will come out to gather food for their offspring." Mr. Birkmann's grandson Roger observed that a week or ten days later "the wild flying and buzzing was renewed several times in fine sunny weather. But when there were indications of rain coming, or in cloudy weather, the bees were not out."

A similar observation was made by my wife (Wilmatte P. Cockerell) in the vicinity of Calvinia, in a dry region of South West Africa. It concerns a totally different but even more peculiar bee, the *Fidelia villosa* Brauns. She has written the following account:

The "white bees" of the desert were full of interest to us all; their adaptation to the grey world of the desert, and their apparent rarity, made us all anxious to secure specimens. Jack Ogilvie took one on the wing, and I was determined to find one at work. I had been so often successful in finding the special bees of the cactus that I felt I must have the same success with these bees of the African desert. My husband thought that probably I should find the bees visiting the small white-flowered *Mesembryanthemum,* then blossoming in great numbers on the desert about us. But we always find collecting poor when there is a great profusion of blossoms; it almost seems that the bee population finds it impossible to keep up with the flowers at the height of their blossoming season. Also we found that the Mesembryanthemums do not have special bees as do most of the cacti, so while I collected numerous bees on the white flowers, I did not find a single *Fidelia,* though I saw two or three flying with a curious drifting motion over the sands or the flowers. One day Alice Mackie and I were collecting; it was a very warm day I remember and we had engaged to have a car meet us

at a certain cross roads to save the walk through the grilling heat. We hurried across the sands, when suddenly we were arrested by a great buzzing sound. There must be a swarm of hive bees about, was my first thought but it proved to be the rare *Fidelia* in numbers, nesting in the sand. It was a wonderful sight, and we stayed to enjoy it for a few minutes, promising ourselves a real study of the colony the next day; but that night there was a heavy rain, and we were obliged to leave before another day of sunshine would get the *Fidelia* to work again. But during the time we were at the nest place we noted that the area was almost as great as a city lot, say 50 feet by 100, and quite full of nest tunnels, arranged of course in groups, since some of the ground was better adapted for nests than other parts. The bees were flying about over this area with the greatest activity, with the curious drifting flight that I had noticed on the few individuals I had seen before. Some of the tunnels were being provisioned, and we saw the females entering with their loads of pollen. Other tunnels were being made and the sand was flying as the little miners carried on their excavations. Here and there I thought I caught sight of a grey fly hovering about. We took a few specimens, and hurried on to our waiting car; had we known that we should have no chance to visit the colony again, the car might have waited. I shall always regret not making a thorough study of this unique bee town.

One might suppose that insects showing so much vigor and such powers of reproduction would spread far and wide, competing successfully against the more ordinary types of bees. This is not at all the case, and it is no doubt true that these insects flourish only in a special kind of environment. Both *Fidelia* and *Protoxaea* appear to be old types, now limited to relatively small areas. The Oxaeidae consist of two genera, *Oxaea* Klug, 1807, and *Protoxaea* Cockerell and Porter, 1899. Owing to the well developed maxillary palpi, we must conclude that *Protoxaea* is the older type. *Oxaea* has ten known species, ranging from Argentina to Mexico. *Protoxaea* consists of *P. gloriosa* (Fox), New Mexico and Arizona; *P. texana* (Friese), first collected by Boll at Dallas, Texas; *P. vagans* (Fox) from Lower California; and *P. impunctata* Cockerell, from the Federal District, Mexico.

The Fideliidae are entirely South African, and consist of *Parafidelia* Brauns, with *P. friesei* Brauns, Bechuanaland, and *P. ornata* Cockerell, Damaraland; and *Fidelia* Friese, with eight species, *F. paradoxa* Friese, *F. villosa* Brauns, *F. kobrowi* Brauns, *F. braunsiana* Friese, *F. major* Friese, *F. aliceae* Cockerell, *F. ogilviae* Cockerell, and *F. alba* Cockerell. They occupy the driest regions of S. Africa, but one has been found in the Transvaal.

T. D. A. Cockerell

University of Colorado